THE ARTIFICIAL Clock-maker.

A Treatise of

Watch, and Clock-work:

Wherein the Art of

Calculating Numbers

For most sorts of

MOVEMENTS

Is explained to the capacity of the Unlearned.

Jn.° ALSO THE Nicholl

History of Clock-work,

Both Ancient and Modern.

With other useful matters never before Published.

By *W. D.* M. A.

LONDON,
Printed for *James Knapton*, at the *Crown* in St. *Pauls* Church-yard, 1696.

Jno: Nicholls his Book
Given him by ye Hoble: Sr
Ed Mansell of margam
Knight & Barronett July
ye 16th 1700

A print of a Cosmagraficall
Clock made by Mr Jon Carte
and sould by ye him and
Jon Horpe att ye black boy
agaynst St Dunstans Church

The Preface.

THe following Book was at firſt drawn up in a rude manner, only to pleaſe my ſelf, and divert the vacant hours of a Solitary Country Life. But it is now publiſhed, purely in hopes of its doing ſome good in the World, among ſuch, whoſe Genius and Leiſure lead them to Mechanical Studies, or thoſe whoſe buſineſs and livelihood it is.

Many there are, whoſe fault, or calamity it is, to have time lying upon their hands; and for want of innocent, do betake themſelves to hurtful pleaſures. This is the too common misfortune of Perſons of Quality. Among ſome of the courſer ſort of theſe, if this Book ſhall find ſome acceptance, it may be a means to compoſe their looſe Spirits; and by an innocent guile, initiate them in other Studies, of greater uſe to themſelves, their family, and country. However it may hinder their commiſſion of many ſins, which are the effects of idleneſs.

If there be any one perſon, in whom theſe good effects are produced, I ſhall think my idle hours well beſtowed, and bleſs God for it. However upon the account of the innocence of my end in publiſhing this Book, and that it was written only as the harmleſs (I

may add alſo the vertuous) ſport of leiſure hours; I think my ſelf excuſable to God and the World, for the expence of ſo much time, in a ſubject different from my Profeſſion.

But beſides, I think my ſelf under ſome little obligations of Juſtice and Charity, to publiſh the enſuing papers for the ſake of thoſe, whoſe buſineſs the Mechanick part is. I take it to be a Charity to the Trade; becauſe there are many (altho excellent in the working part) who are utterly unskilled in the artificial part of it. And then, it is a debt I pay: becauſe I owe ſomewhat of health, as well as diverſion to the Study, and practice of theſe ſort of Mechanicks. And the beſt requital I can make for my treſpaſs, is to publiſh what I have had better opportunities perhaps of Learning, than many Workmen have.

And further yet, there is another reaſon, which much prevailed with me to publiſh this Book, *viz.* Becauſe no body, that I know of, hath prevented me, by treating ſo plainly and intelligibly of this ſubject, as to be underſtood by a vulgar Workman. I have often wondered at it, that ſo uſeful and delightful a part of Mechanical Mathematicks ſhould lie in any obſcurity, in an age wherein ſuch vaſt improvements have been made therein, and when many Books are daily publiſhed upon every ſubject. I ſpeak here of this Art remaining in obſcurity; not as if nothing was ever written of it, and I the

In

inventer of Automatical Computation.

But altho I cannot assume the glory of being the first Writer upon this subject, yet very few have as yet done it; of which I shall next give some account.

Cardan, *Kircher*, and *Scottus* promised it; but I do not find they ever published any thing to the purpose of it. Our great Mr. *Oughtred* I take to be the first that ever wrote to any purpose about the Calculation of *Automata*: And I believe he was the first that brought that Art under Rules, in his little treatise called *Automtaa.* This Book was first surreptitiously published in *English* in a little Book, called *Horolog. Dialogues*, in the year 1675; and afterwards far more compleatly in *Latin*, at the Theatre in *Oxon*, among Mr. *Oughtred's Opusc. Mathem.* in the year 1677. This last edition it was my misfortune not to meet with, until it was too late, and therefore I have been forced to quote the first, and worst in my Book.

What Mr. *Oughtred* had wrapt up in his Algebraick obscure Characters, was afterwards put into plainer Language, by that excellent Mathematician Sir *Jon. Moor*, with some additions of his own; which you have in his *Math. Compend.* and since him, by Mr. *Leyborne*, in his *Pleasure with Profit.*

I hope I shall not be judged to have transgressed the Rules of Modesty, in coming after three such famous men; neither should I

venture that cenſure, but for two reaſons. One is, I find by experience, that what they have written, is underſtood by very few Workmen. And therefore I have endeavoured, with all induſtry, to make the matter as plain as I could for ſuch. For which reaſon, I hope the more learned Reader will excuſe my uſing many words, when fewer would have ſerved *his* turn; and that I have condeſcended to low things, (and to him needleſs) as teaching the Golden-rule, *&c.* The other reaſon is, that what thoſe three have written, relates only, or chiefly to the Watch-part. To which I have added ſeveral other things of my own: particularly the Calculation of the Clock-part, *&c.* I have been forced to reduce to Rules my ſelf, and to name no more, the Hiſtorical part hath not been ſo much as attempted before, that I know of.

Theſe Reaſons will, I hope, excuſe me with the moſt cenſorious Reader, not only for preſuming to write after ſo accurate a piece, as Mr. *Oughtred*'s is; but alſo the Novelty of the ſubject, will I hope procure for me a candid interpretation of the faults and blunders, that I may have unwittingly committed.

To the preceeding account of what others have written (which ſhews what help I have had from printed Books) I ſhall ſubjoyn my acknowledgments, and thanks to the principal of my friends, who have given me their aſſiſtance in compiling this Book. But their

name

names I ſhall not make more publick than mine own, being unwilling to be diſcovered my ſelf. In the Chap. of the Terms of Art, I owe much to the aſſiſtance of *L. Br.* . . . a judicious Workman in *White-chappel*, who drew me up a Scheme of the Clock-maker's Language. In the Hiſtory of the Modern Inventions, I have had (among ſome others) the aſſiſtance chiefly of the ingenious *Dr. H.* . . . and *Mr. T.* . . . : The former being the Author of ſome, and well acquainted with others, of the Mechanical Inventions of that fertile Reign of King *Charles* the II. and the latter actually concerned in all, or moſt of the late inventions in Clock-work, by means of his famed skill in that, and other Mechanick operations.

There are ſome other contrivances of this laſt age (beſides thoſe I have mentioned) which I have paſſed over in ſilence; becauſe either they are only branches, or improvements of the inventions I have taken notice of, (ſuch as ſeveral ways of repeating work, *&c.*) or elſe, they only collaterally relate to Watch-work (as the inventions of Cutting-Engines, Fuſy-Engines, *&c.*) To treat of all theſe, would ſwell my Book far beyond its intended bounds; which I have already ſomewhat exceeded. I ſhall therefore commit this task to ſome better Pen, hoping that no perſon will take it amiſs, that I have not mentioned what I have been beholding to him for the relation of.

For the reſons laſt mentioned, I have alſo left out of my Book, a Chapter of the Art of making, and uſing many ſorts of Sodders, the way of colouring Metals, *&c.* uſeful in the practice of Clock-work. This I had prepared for the ſake of Mercurial Gentlemen, but omitted printing it, and ſome other things, out of Charity to poor Apprentices and other Workmen, whoſe purſes I am unwilling my volume ſhould too much exceed.

If I have at any time invaded the Workman's province, it was not becauſe I pretend to teach him his Trade; but either for Gentlemen's ſakes, or when the matter led me neceſſarily to it.

I have nothing more to add, but that I would have this little Treatiſe looked upon only as an Eſſay, which I hope will prompt ſome abler pen to perform the task better, eſpecially in the Hiſtorical part. For ſince Watch-work oweth ſo much to our Age, and Country, tis pity that it ſhould not be remembred: eſpecially when we cannot but lament the great defect of Hiſtory, about the beginning and improvements of this ingenious and uſeful Art.

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THE

The Artificial CLOCK-MAKER.

CHAP. I.

Of the Terms of Art, or Names by which the parts of an Automaton *are called.*

IT is neceſſary that I ſhould ſhew the meaning of thoſe Terms which Clock-makers uſe, that Gentlemen and others, unskilful in the Art, may know how to expreſs themſelves properly, in ſpeaking; and alſo underſtand what I ſhall ſay in the following Book.

I ſhall not trouble the Reader with a recital of every name that doth occur, but only ſuch as I ſhall have occaſion to

uſe in the following diſcourſe, and ſome few others that offer themſelves, upon a tranſient view of a piece of work.

I begin with the more general Terms: as, the *Frame*; which is that which contains the Wheels, and the reſt of the work. The *Pillars*, and *Plates*, are what it chiefly conſiſts of.

Next for the *Spring*, and its appurtenances. That which the Spring lies in, is the *Spring-box*; that which the Spring laps about, in the middle of the Spring-box, is the *Spring-Arbor*; to which the Spring is hooked at one end. At the top of the Spring-Arbor, is the *Endleſs-Screw*, and its Wheel.

That which the Spring draweth, and about which the Chain or String is wrapped, and which is commonly taper, is the *Fuſy*. In larger work, going with weights, where it is cylindrical, it is called the *Barrel*. The ſmall Teeth at the bottom of the Fuſy, or Barrel, that ſtop it in winding up, is the *Ratchet*. That which ſtops it when wound up, and is for that end driven up by the String, is the *Garde-caut*, or *Guard-Cock*, as others; and *Garde-du-Cord*, and *Gard-du-Gut*, as others call it. The

The parts of a *Wheel* are, the *Hoop*, or *Rim*: the *Teeth*: the *Croſs*: and the *Collet*, or piece of Braſs, ſoddered on the Arbor, or Spindle, on which the Wheel is rivetted.

A *Pinion* is that little Wheel, which plays in the teeth of the Wheel. Its teeth (which are commonly 4, 5, 6, 8, &c.) are called *Leves*, not Teeth.

The ends of the Spindle, are called *Pevetts*: the holes in which they run, *Pevet-holes*.

The guttered Wheel, with Iron ſpikes at the bottom, in which the line of ordinary Houſe-Clocks doth run, is called the *Pully*.

I need not ſpeak of the *Dial-plate*, the *Hand*, *Screws*, *Wedges*, *Stops*, &c.

Thus much for general Names, which are common to all parts of a Movement.

The parts of a *Movement*, which I ſhall conſider, are the *Watch*, and *Clock*.

The *Watch-part* of a Movement is that which ſerveth to the meaſuring the hours. In which the firſt thing I ſhall conſider is the *Ballance*: whoſe parts are, the *Rim*, which is the circular part of it: the *Verge*, is its Spindle: to which belong the two

Pallets, or *Nuts*, which play in the fangs of the Crown-Wheel: in Pocket-Watches, that ſtrong Stud in which the lower Pevet of the Verge plays, and in the middle of which one Pevet of the Crown-Wheel runs, is called the *Pottans*: the wrought piece which covers the Ballance, and in which the upper Pevet of the Ballance plays, is the *Cock*. The ſmall Spring in the new Pocket-Watches is the *Regulator*.

The parts of a *Pendulum* are, the *Verge*, *Pallets* and *Cocks*, as before. The *Ball* in long Pendulums, the *Bob* in ſhort ones, is the Weight at the bottom. The *Rod*, or *Wire* is plain. The terms peculiar to the *Royal Swing*, are the *Pads*, which are the Pallets in others, and are fixed on the *Spindle*. The *Fork* is alſo fixed on the Spindle, and about 6 inches below, catcheth hold on the Rod, at a flat piece of Braſs, called the *Flatt*, in which the lower end of the *Spring* is faſtened.

The names of the Wheels next follow. The *Crown-Wheel* in Small pieces, and *Swing-Wheel* in Royal Pendulums, is that Wheel which drives the Ballance, or Pendulum. The

The *Contrate-Wheel*, is that Wheel in Pocket-Watches, which is next to the Crown-Wheel, whoſe Teeth and Hoop lye contrary to thoſe of other Wheels.

The *Great-Wheel*, or *Firſt-Wheel*, is that which the Fuſy, &c. immediately driveth. Next it, are the *Second-Wheel*, *Third-Wheel*, &c.

Next followeth the Work between the Frame and Dial-Plate. And firſt, is the *Pinion of Report*; which is that Pinion which is commonly fixed on the Arbor of the Great-Wheel, and in old Watches uſed to have commonly but four Leaves; which driveth the *Dial-Wheel*, and this carrieth about the *Hand*.

The laſt Part which I ſhall ſpeak of, is the *Clock*, which is that part which ſerveth to ſtrike the Hours: In which I ſhall

Firſt ſpeak of the *Great*, or *Firſt-Wheel*; which is that which the Weight or Spring firſt drives. In 16 or 30 hour Clocks, this is commonly the *Pin-Wheel*; in 8 Day pieces, the *Second-Wheel* is commonly the *Pin-Wheel*. This Wheel with Pins is ſometimes called the *Striking-Wheel*, or *Pin-Wheel*.

Next

Next to this Striking-Wheel, follow-
eth the *Detent-Wheel*, or *Hoop-Wheel*,
having a Hoop almost round it, in which
is a vacancy, at which the Clock
locks.

The next is the *Third*, or *Fourth*
Wheel (according as it is distant from
the First-Wheel) called also the *Warning*
Wheel.

And lastly is the *Flying-Pinion*, with
a *Fly* or *Fan* to gather Air, and so bridle
the rapidity of the Clock's motion.

Besides these, there are the *Pinion* of
Report, of which before; which driveth
round the *Locking-Wheel*, called also the
Count-Wheel, with 11 Notches in it com-
monly, unequally distant from one ano-
ther, to make the Clock strike the hours
of 1, 2, 3, &c.

Thus much for the Wheels of the
Clock part.

Besides which there are the *Rash*, or
Ratch; which is that sort of Wheel, of
twelve large Fangs, that runneth concen-
trical to the Dial-Wheel, and serveth to
lift up the Detents every hour, and
make the Clock strike.

The *Detents* are those Stops, which
by

by being lifted up, or let fall down, do lock and unlock the Clock in ſtriking.

The *Hammers* ſtrike the Bell: The *Hammer-tails* are what the Striking-pins draw back the Hammers by.

Latches are what lift up, and unlock the Work.

Catches are what hold by hooking, or catching hold of.

The *Lifting-pieces* do lift up, and unlock the Detents, in the Clock part.

CHAP. II.

The Art of Calculation.

SECT. I.

General preliminary Rules and Directions for Calculation.

§ 1. FOR the more clear underſtanding this Chapter it muſt be obſerved, that thoſe *Automata* (whoſe *Calculation* I chiefly intend) do by little Interſtices, or Strokes, meaſure out longer portions

portions of *Time*. Thus the ſtrokes of the Ballance of a Watch, do meaſure out Minutes, Hours, Days, *&c.*

Now to ſcatter thoſe ſtrokes among *Wheels* and *Pinions*, and to *proportionat* them, ſo as to meaſure Time regularly, is the deſign of Calculation. For the clearer diſcovery of which, it will be neceſſary to proceed leiſurely, and gradually.

Oughtred of Autom. ſect. 4.

§ 2. And in the firſt place, you are to know, that any Wheel being divided by its Pinion, ſhews how many *turns* that Pinion hath to one turn of that Wheel. Thus a Wheel of 60 teeth driving a Pinion of 6, will turn round the Pinion 10 times in going round once.

From the Fuſy to the Ballance the Wheels drive the Pinions; and conſequently the Pinions run faſter, or go more turns, than the Wheels they run in. But it is contrary from the Great-Wheel to the Dial Wheel. Thus in the laſt Example, The Wheel drives round the Pinion 10 times: but if the Pinion drove the Wheel, it muſt turn 10 times to drive the Wheel round once.

§ 3. Before I proceed further, I muſt ſhew

ſhew how to *write down* the Wheels and Pinions. Which may be done, either as Vulgar Fractions, or in the way of Diviſion in Vulgar Arithmetick. E. C. A Wheel of 60 moving a Pinion of 5, may be ſet down thus, $\frac{60}{5}$: or rather thus, 5)60 : where the firſt figure is the Pinion, the next without the hook, is the Wheel.

The number of Turns, which the Pinion hath in one turn of the Wheel, is ſet without a hook on the right hand: as 5)60(12, *i. e.* a Pinion 5 playing in a Wheel of 60, moveth round 12 times, in one turn of the Wheel.

A whole Movement may be noted thus, $\frac{4}{36}$ $\frac{11}{55}$ $\frac{9}{45}$ $\frac{8}{40}$ 17 Notches in the Crown-Wheel. Or rather as you ſee here in the Margin: where the uppermoſt number, above the line, is the Pinion of Report 4, the Dial-wheel 36, and 9 turns of the Pin. of Report. The ſecond number (under the line) is 5 the Pinion, 55 is the Great-wheel, and 11 turns of the Pinion it driveth. The third numbers, are the Second-wheel, &c.

4)36(9
5)55(11
5)45(9
5)40(8
17

The fourth the Contrate-wheel, &c. And the ſingle number 17 under all, is the Crown-wheel.

§ 4 By the § 2. before, knowing the number of turns, which any Pinion hath in one turn of the Wheel it worketh in, you may alſo find out how many turns a Wheel or Pinion hath, at a greater diſtance; as the Contrate-wheel, Crown-wheel, or &c. For it is but multiplying together the *Quotients*, and the number produced, is the number of Turns. An Example will make what I ſay plain: let us chuſe theſe 3 numbers here ſet down; the firſt of which hath

5)55(11
5)45(9
5)40(8

11 turns, the next 9, and the laſt 8. If you multiply 11 and 9 it produceth 99, for 9 times 11 is 99, that is, in one turn of the Wheel 55, there are 99 turns of the ſecond Pinion 5, or of the Wheel 40. If you multiply 99 by the laſt Quotient 8 (that is, 8 times 99 is 792) it ſhews the number of turns, which the third and laſt Pinion 5 hath. So that this third, and laſt Pinion turns 792 times in one

By the Quotients I commonly mean the number of Turns; which number is ſet on the right hand, without a hook, as is ſhewn in the laſt Paragraph. Which I note here now once for all.

one turn of the first Wheel 55. Another Example will make it still more plain The Example is in the Margin The turns are 10, 9 and 8. These multiplied as before run thus, *viz.* 10 times 9 is 90, that is, the Pinion 6 (which is the Pin. of the third Wheel 40) turns 90 times in one turn of the First-wheel 80. This last product 90 being multiplied by 8, produces 720; that is, the Pinion 5 (which is the Pin. of the Crown-wheel 15) turns 720 times in one turn of the First-wheel, of 80 teeth.

8)80(10
6)54(9
5)40(8
—
15

§ 5. We may now proceed to that, which is the very groundwork of all; which is, not only to find out the turns, but the *Beats* also of the Ballance in those turns of the Wheels. By the last Paragraph, having found out the number of turns, which the *Crown-wheel* hath in one turn of the Wheel you seek for, you must then multiply those turns of the Crown-wheel by its number of Notches, and this will give you half the number of *Beats*, in that one turn of the Wheel. Half the number, I say, for the reasons in the following

lowing 6 §. For the Explication of what hath been ſaid, we will take the example in the laſt §: the Crown-wheel there, has 720 turns in one turn of the firſt Wheel: This number multiplied by 15, the Notches in the Crown-wheel, produceth 10800, which are half the number of ſtrokes of the Ballance, in one turn of the firſt wheel 80. The like may be done for any of the other Wheels; as the Wheel 54, or 40: but I ſhall not inſiſt upon theſe, having ſaid enough.

I ſhall give but one Example more, which will fully, and very plainly illuſtrate the whole matter. The example is in the margin, and 'tis of a 16

4)32(8
5)55(11
5)45(9
5)40(8
17

hour Watch, wherein the Pinion of Report is 4, the Dial-wheel 32, the Great-wheel 55, the Pinion of the ſecond Wheel is 5, &c. the number of Notches in the Crown-wheel are 17: the quotients or number of turns in each, are 8, 11, 9, 8. All which being multiplied as before, make 6336: this number multiplied by 17, produceth 107712; which laſt ſumm is half the number of Beats in one

tur

turn of the Dial-wheel. The half number of Beats in one turn of the Great-wheel, you will find to be 13464: For 8 times 17 is 136, which is the half number of Beats in one turn of the Contrate-wheel 40: and 9 times 136, is 1224, the half beats in one turn of the Second-wheel: and 11 times 1224, is 13464, the half beats in one turn of the Great-wheel 55. And 8 times this laſt, is 107712 before named. If you multiply this by the two Pallets, that is, double it, it is 215424, which is the number of Beats in one turn of the Dial-wheel, or 12 hours. If you would know how many beats this Watch hath in an hour, 'tis but dividing the beats in 12 hours, into 12 parts, and it gives 17952, the Train of the Watch, or beats in an hour. If you divide this into 60 parts, it gives 299 and a little more, for the beats in a minute. And ſo you may go on to ſeconds and thirds, if you pleaſe.

Sir *J. Moor* Mat. Com. p. 109.

Thus I have delivered my thoughts as plainly as I can, that I may be well underſtood; this being the very foundation of all the artificial part of Clock-work. And therefore let the young practiſer exercise

ercise himself thorowly in it, in more than one example.

If I have offended the more learned, quick-sighted Reader, by using many words; my desire to instruct the most ignorant Artist, must plead my excuse.

Ibid. p. 116. § 6. The Ballance or Swing hath two strokes to every tooth of the Crown-wheel. For each of the two Pallets hath its blow against each tooth of the Crown-wheel: Wherefore a Pendulum that swings Seconds, hath its Crown-wheel but 30.

SECT. II.

The way to Calculate, or contrive the Numbers of a piece of Watch work.

HAving in the last Section led on the Reader to a general knowledge of Calculation; I may now venture him further into the more obscure, and useful parts of that Art: Which I shall explain with all possible plainness, tho less brevity, than I could wish.

Oughtred Autom. Sect. 14. § 1. The same motion may be performed either with one Wheel and one Pini-

Pinion; or by many Wheels and many Pinions: provided that the number of turns of all thoſe Wheels bear the ſame proportion to all thoſe Pinions, which that one Wheel bears to its Pinion. Or (which is the ſame thing) that the number produced by multiplying all the Wheels together, be to the number produced by multiplying all the Pinions together; as that one Wheel is to that one Pinion. Thus ſuppoſe you had uſe for a Wheel of 1440 teeth, with a Pin. of 28 leaves, you may make it into 3 Wheels and Pinions, *viz.* 4, 36, 7)8, and 1)5. For if you multiply the three Wheels together, *viz.* 36, 8 and 5; and the three Pinions together by themſelves, *viz* 4, 7 and 1, you will find 1440 to ariſe for the Wheels, and 28 for the Pinions. Or if you try the example by the number of turns, it will be the ſame. For 28)1440 (51 $\frac{3}{7}$. And the quotients and turns of the 3 Wheels and Pinions multiplied together, are 51 $\frac{3}{7}$ alſo, as in the laſt example.

28)1440

It matters not in what order the Wheels and Pinions are ſet, or which Pinion runs in

in which Wheel: Only for convenienc
ſake, they commonly ſet the biggeſt num
bers to drive the reſt.

§ 2. Two Wheels and Pinions of diffe
Ought. ib. rent numbers may perform the ſame mo
tion. As, a Wheel of 36 drives a Pinio
of 4, all one as a Wheel of 45 drives
Pin. of 5; or as a Wheel of 90 drives
Pin. of 10. The turns of each are 9.

§ 3. If in breaking your Train int
parcels (of which by and by) any of you
Quotients ſhould not pleaſe you; or
Id. ib. you would alter any other two numbe
which are to be multiplied together, yo
may vary them by this Rule: Divid
your two numbers by any two othe
numbers which will meaſure them; the
multiply the Quotients by the alterna
diviſors, the product of theſe two la
numbers found, ſhall be equal to the pr
duct of the two numbers firſt give
Thus if you would vary 36 times 8, d
vide theſe by any two numbers that wi
evenly meaſure them, as 36 by 4, and
by 1. The fourth part of 36 is 9, and
divided by 1 gives 8. Multiply 9 by
the product is 9; and 8 multiplied by
produceth 32. So that for 36 times 8
yo

9 8
36 x 8
4 1
——
32 x 9

you ſhall have found 32 times 9. The operation is in the Margin, that you may ſee, and apprehend it the better. Theſe numbers are equal, *viz.* 36 times 8 is equal to 32 times 9; both producing 288. If you divide 36 by 6, and 8 by 2, and multiply as before is ſaid, you will have for 36 times 8, 24 times 12, equal to 288 alſo.

If this Rule ſeem to the unskilful Reader hard to be underſtood, let him not be diſcouraged, becauſe he may do without it, altho it may be of good uſe to him that would be a more compleat Artiſt.

§ 4. Becauſe in the following Paragraphs, I ſhall have frequent occaſion to uſe the *Rule of Three*, or *Rule of Proportion*, it will be neceſſary to ſhew the unskilful Reader, how to work this noble Rule.

If you find 3 or 4 numbers thus ſet, with four ſpots after the ſecond of them, 'tis the Rule of Proportion; as in this example, 2. 4 :: 3. 6. *i. e.* As 2 is to 4 :: So is 3 to 6.

The way to work this Rule, *viz.* by the 3 firſt numbers to find a fourth, is,

To multiply the ſecond number and the third together, and divide their product by the firſt. Thus 4 times 3 is 12, which 12 divided by 2, gives 6; which is the number ſought for, and ſtands in the fourth place.

You will find the great uſe of this Rule hereafter; only take care to bear it in mind all along.

§ 5. To proceed. If in ſeeking for your Pinion of Report, or by any other means, you happen to have a Wheel and Pinion fall out with croſs numbers, too big to be cut in Wheels, and yet not to be altered by the former Rules, you may find out two numbers of the ſame, or a near proportion, by this following Rule, *viz.* As either of the two numbers given, is to
Id. ib. the other :: So is 360 to a fourth: Divide that fourth number, as alſo 360 by 4. 5. 6. 8. 9. 10. 12. 15. (each of which numbers doth exactly meaſure 360) or by any one of thoſe numbers that bringeth a quotient neareſt to an integer (or whole number.) Thus if you had theſe two numbers, 147 the Wheel, and 170 the Pinion, which are too great to be cut in ſmall Wheels, and yet can't be reduced into

into leſs, becauſe they have no other common meaſure, but unity: ſay therefore according to the laſt paragraph, As 170 is to 147; or as 147 is to 170:: So is 360 to a fourth number ſought. In numbers thus, 170 147 :: 360. 311. or 147. 170 :: 360. 416. Divide the fourth number and 360 by one of the foregoing numbers; as 311 and 360 by 6, it gives 52 and 60. In numbers 'tis thus, 6)311(52 / 360(60 Divide by 8 'tis thus, 8)311(39 / 360(45 If you divide 360 and 416 by 8, it will fall out exactly to be 45 and 52 8)360(45 / 416(52 Wherefore for the two numbers 147 and 170, you may take 52 and 60; or 39 and 45; or 45 and 52, or *&c.*

§ 6. I ſhall add but one Rule more, before I come to the practice of what hath been laid down; which Rule will be of perpetual uſe, and conſiſts of theſe five particulars.

1. To find what number of turns the Fuſy will have, thus, As the Beats of the Ballance in one turn of the Great-Wheel or Fuſy (ſuppoſe 26928) To the Beats of the Ballance in one hour (ſuppoſe 20196) :: So

Oughtred Sect. 12. Sir *J. Moor* Ibid. p. 109.

:: So is the continuance of the Watches going in hours (ſuppoſe 16) To the number of the turns of the Fuſy 12. In numbers 'twill ſtand thus, 26928. 20196 :: 16. 12. By § 4. you may remember that you are to multiply 20196 by 16, the product is 323136. Divide this by 26928, and there will ariſe 12 in the Quotient, which muſt be placed in the fourth place, and is the number of turns which the Fuſy hath.

2. By the Beats and turns of the Fuſy, to find how many hours the Watch will go, thus,

As the Beats of the Ballance in one hour, are to the Beats in one turn of the Fuſy:: So is the number of the turns of the Fuſy, to the continuance of the Watches going. In numbers thus,

2196. 26928:: 12. 16.

3. To find the ſtrokes of the Ballance in one turn of the Fuſy, ſay, As the number of turns of the Fuſy, to the continuance of the Watch's going in hours:: So are the Beats in one hour, to the Beats of one turn of the Fuſy. In numbers it is thus,

12. 16:: 20196. 26928.

4. T

4. To find the Beats of the Ballance in an hour, ſay thus, As the hours of the Watch's going, To the number of turns of the Fuſy :: So are the Beats in one turn of the Fuſy, To the Beats in an hour. In numbers thus,

16. 12 :: 26928. 20196.

5. To find what Quotient is to be laid upon the Pinion of Report, ſay thus, As the beats in one turn of the Great-wheel, To the beats in an hour :: So are the hours of the Face of the Clock (*viz.* 12 or 24) To the Quotient of the Hour-Wheel divided by the Pinion of Report, *i. e.* the number of turns, which the Pinion of Report hath in one turn of the Dial-Wheel. In numbers thus,

26928. 20196 :: 12. 9.

Or rather (to avoid trouble) ſay thus, As the hours of the Watch's going, Are to the numbers of the turns of the Fuſy :: So are the hours of the Face, To the Quotient of the Pinion of Report. In numbers thus, 16. 12 :: 12. 9. If the hours of the Face be 24, the Quotient will be 18; thus, 16. 12 :: 24. 18.

§ 7. Having given a full account of all things neceſſary to the underſtanding the

Art

Art of Calculation, I ſhall now reduce what hath been ſaid into practice, by ſhewing how to proceed, in Calculating a piece of Watch-work.

The firſt thing you are to do, is to pitch upon your Train, or beats of the Ballance in an hour: as, whither a ſwift Train, about 20000 beats (which is the uſual Train of a common 30 hour Pocket-Watch) or a ſlower Train of about 16000 (the Train of the new Pendulum Pocket-Watches;) or any other Train.

Having thus pitched upon your Train, you muſt next reſolve upon the number of turns you intend your Fuſy ſhall have; and alſo upon the number of Hours, you would have your Piece to go: As ſuppoſe 12 turns; and to go 30 hours, or 192 hours (which is 8 days) or *&c.*

Theſe things being all ſoon determined; you next proceed to find out the beats of the Ballance, or Pendulum, in one turn of the Fuſy, by the laſt § 6 part 3. *viz.* As the turns of the Fuſy, To the hours of the Watch's going :: So is the Train, To the number of beats in one turn of the Fuſy. In numbers thus, 12. 16 :: 20000. 26666. Which laſt num-

number are the beats in one turn of the Fuſy, or Great-Wheel; and (by Sect. I. § 5. of this Chap.) are equal to the Quotients of all the Wheels unto the ballance, multiplied together. This number therefore is to be broken into a convenient parcel of Quotients: which you are to do after this manner. Firſt, half your number of beats, *viz.* 26666, for the reaſons in Sect. I. § 6. of this Chap. the half whereof is 13333. Next you are to pitch upon the number of your Crown-wheel, as ſuppoſe 17. Divide 13333 by 17, the Quotient will be 784 (or to ſpeak in the language of one that underſtands not Arithmetick, divide 13333 into 17 parts, and 784 will be one of them.) This 784 is the number left for the Quotients (or turns) of the reſt of the Wheels and Pinions: which being too big for one or two Quotients, may be beſt broken into three. Chuſe therefore 3 numbers, which when multiplied all together continually will come neareſt 784. As ſuppoſe you take 10, 9, and 9. Now 10 times 9 is 90; and 9 times 90 is 810, which is ſomewhat too much. You may therefore try again other numbers, as ſuppoſe 11, 9, and 8.

Theſe

These multiplied as the last, produce 792 which is as near as can be, and convenient Quotients.

Thus you have contrived your Piece from the Great-Wheel to the Ballance But the numbers not falling out exactly according as you at first proposed; you must correct your work thus. First to find out the true number of beats, in one turn of the Fusy, you must multiply 792 aforesaid, which is the true product of all the Quotients, by 17, the notches of the Crown-wheel; the product of this is 13464, which is half the number of true beats in one turn of the Fusy, by Sect. I § 5. of this Chap. Then to find the true number of beats in an hour, say by § 6 part 4. of this Section, as the hours of the Watch's going, *viz.* 16, to the 1 turns of the Fusy :: So is 13464 the ha beats in one turn of the Fusy, to 1009 the half beats in an hour: the numbe will stand thus 16. 12 :: 13464. 1009

Then to know what Quotient is to b laid upon the Pinion of Report, say by 6. part 5. of this Sect: As the hours the Watch's going, *viz.* 16, to the tur of the Fusy, *viz.* 12:: So are the hou

of the Dial-plate, *viz.* 12, To the Quotient of the Pinion of Report. In numbers thus, 16. 12 :: 12. 9.

Having thus found out all your Quotients, 'tis eaſie to determine what numbers your Wheels ſhall have: for chuſe what numbers your Pinions ſhall have, and multiply the Pinions by their Quotients, and that produceth the numbers for your Wheels, as you ſee in the Margin. Thus 4 is the number of your Pinion of Report, and 9 its quotient; therefore 4 times 9, which makes 36, is the number for the Dial-wheel. So the next Pinion being 5, and its quotient 11, this multiplied produces 55 for the Great-wheel. And the like of the reſt of the following numbers.

4)36(9
5)55(11
5)45(9
5)40(8
17

Thus, as plain as words can expreſs it, I have ſhewed how to Calculate the numbers of a 16 hour Watch.

§ 8. This Watch may be made to go a longer time, by leſſening the Train, and altering the Pinion of Report. Suppoſe you could conveniently ſlacken the Train to 16000, the half of which is 8000. *Oughtred* Sect. 21.

§ 8. Then ſay (by §. 6 part 2. of this Sect.) As the halfed Train, or Beats in an hour, *viz.* 8000, To the halfed beats in one turn of the Fuſy, *viz.* 13464 :: So are the turns of the Fuſy, *viz.* 12, To the hours of the Watch's going: in numbers thus, 8000. 13464 :: 12. 20 So that this Watch will go 20 hours.

Then for the Pinion of Report, ſay, by the ſame §, part 5, As 20 the Continuance; To 12 the turns of the Fuſy :: So are 12 the hours of the Face, To 7 the quotient of the Pinion of Report. In numbers thus, 20. 12 :: 12. 7.

The work is the ſame as before, as to the numbers; only the Dial-wheel is but 28, becauſe its quotient is altered to 7; as appears in the Margin, by the Scheme of the work.

4)28(7
5)55(11
5)45(9
5)40(8
17

§ 9. I ſhall give the Reader one example more, for the ſake of ſhewing him the uſe of ſome of the foregoing Rules, not yet taken notice of in the former operations. Suppoſe you would give numbers to a Watch of about 10000 beats in an hour, to have 12 turns

Id. ib. § 22.

of

of the Fuſy, to go 170 hours, and 17 notches in the Crown-wheel.

This work is the ſame as in the laſt Example § 7. In ſhort therefore thus, As the turns 12: are To the Continuance 170:: So is the Train 10000, To 141666, which are the beats in one turn of the Fuſy. The numbers will ſtand thus, 12. 170 :: 10000 141666. Half this laſt is 70833. Divide this half into 17 parts, and 4167 will be for the quotients. And becauſe this number is too big for 3 quotients, therefore chuſe 4: as ſuppoſe 10, 8, 8, and 6 $\frac{3}{5}$ (*i. e.* 6 and 3 fifths) Theſe multiplied together as before, and with 17, maketh 71808, which are half the true beats in one turn of the Fuſy. By this you are to find out your true Train firſt, ſaying as in the former example, As 170 to 12 :: So 71808, to 50695 which laſt is the half of the true Train of your Watch. Then for the Pinion of Report, ſay, as 170, to 12 :: So 12, to $\frac{144}{170}$. Which Fraction ariſeth thus: If you multiply 12 by 12 it makes 144 5 and divide 144 by 170, you cannot; but ſetting the 144 (the dividend) over 170 (the Diviſor) and there ariſeth this fraction $\frac{144}{170}$.

which is a Wheel and Pinion; the lower is the Pinion of Report, and the upper is the Dial-wheel, according to Sect. I. § 3. of this Chapter. Or (which perhaps will be more plain to the unlearned Reader) you may leave those two numbers, in their Divisional posture thus, 170)144, which does express the Pinion and Wheel, in the way I have hitherto made use of.

But to proceed. These numbers being too big to be cut in small Wheels, may be varied, as you see a like Example is § 5. of this Section: *viz.* Say, as 144. is To 170 :: So is 360, To 425. Or, as 170, to 144 :: So is 360, To 305. In number thus, 144. 170 :: 360. 425. Or 170. 144 :: 360. 305. Divide 360, and either of these two fourth and last numbers by 4, 5, 6, 8, *&c.* (as is directed in the Rule last cited.) If you divide by 8, you will have for your numbers $\frac{144}{170}$ $\frac{45}{53}$ or $\frac{18}{53}$. If you divide by 15 (which will not bring it so near an integer) you will have $\frac{24}{28}$ or $\frac{20}{34}$: which last are the numbers set down in the Margin.

24)20($\frac{20}{24}$
6)60(10
6)48(8
5)40(8
5)33($6\frac{3}{5}$
17

gin

gin; where the numbers of the whole Movement are ſet down.

§ 10. Having ſaid enough, I think, concerning the Calculation of ordinary Watches, to ſhew the hour of the day: I ſhall next proceed to ſuch as ſhew minutes and ſeconds. The proceſs whereof is thus; Firſt, having reſolved upon your beats in an hour, you are next to find how many beats there will be in a minute, by dividing your deſigned Train into 60 parts. And accordingly you are to find out ſuch proper numbers for your Crown-wheel, and quotients, as that the Minute-wheel ſhall go round once in an hour, and the Second-wheel once in a minute.

An Example will make all plain. Let us chuſe a Pendulum of 6 inches to go 8 days, with 16 turns of the Fuſy. By Mr *Smith*'s Tables, a Pendulum of 6 inches vibrates 9368 in an hour. This divided by 60 gives 156 beats for a minute. Half theſe ſumms are 4684 and 78. Now the firſt work is to break this 78 into good proportions; which will fall into one quotient, and the Crown-wheel. Firſt, for the Crown-wheel; let it

Horol. Diſq. Sect. 1. § 6.

it have 15 notches. Divide 78 aforesaid by this 15, the quotient will be 5. And so this first work is done: for a Crown wheel of 15, and a Wheel and Pinion, whose quotient is 5 (in the Margin) will go round in a minute, to carry a Hand to shew *Seconds*.

8)40(5
15

Next for a Hand to go round in an hour, to shew *Minutes*. Now because there are 60 minutes in an hour, 'tis best breaking 60 into two good quotients (which may be many) and 6, or 8 and 7 ½, or &c. and the work is done.

8)64(8
8)60(7½
8)40(5
15

Thus your number 4684, broken, as near as can be, into proper numbers.

But because it does not fall out exactly into the above-mentioned numbers, you must Correct (as you were directed before) and find out the true number of beats in an hour, by multiplying 15 by 5, which makes 75; and this by 6 makes 4500, which is the half of the true Train. Then to find out the beats in one turn of thy Fusy, operate as before, *viz.* As the number of turns, 16, To the con-

§6. Par. 3. and §7.

tinuance

finuance 192 :: So is 4500 to 54000, which are half the beats in one turn of the Fuſy. In numbers thus, 16. 192 :: 4500. 54000. This 54000 muſt be divided by 4500, which are the true numbers already pitched upon, or beats in an hour. The quotient of this diviſion is 12, which being not too big for one ſingle quotient, needs not be divided into more. The work will ſtand, as you ſee in the Margin.

```
)108(12
 ) 64(8
 ) 60(7½
 ) 40(5
 ----
   15
```

As to the Hour-hand, the Great-Wheel, which performs only one revolution in 12 turns of the Minute-wheel, will ſhew the hour. Or rather you may order it to be done by the Minute-wheel, as ſhall be ſhew'd hereafter.

§ 11. I ſhall add but one Example more, and ſo conclude this Section; and that is, To calculate the numbers of a piece whoſe Pendulum ſwings Seconds, to ſhew the hour, minutes, and ſeconds, and to go 8 days; which is the uſual performance of thoſe Movements called Royal Pendulums at this day. Firſt, caſt up the number of ſeconds in 12 hours (which

Sir *J. Moor* Ibid. p. 116.

(which are the beats in one turn of t
Great-wheel) Theſe are 12 times
minutes, and 60 times that, gives 432
which are the ſeconds in 12 hours. H
this number (for the reaſons before)
V. Sect. 1. § 6. 21600. The Swing-wheel muſt ne
be 30, to ſwing 60 ſeconds in one of
revolutions. Divide 21600 by it, t
720 is the quotient, or number left to
broken into quotients. Of theſe quo
ents, the firſt muſt needs be 12 for t
Great-wheel, which moves round on
in 12 hours. Divide 720 by 12, t
quotient is 60; which may be conve
ently broken into two quotients, as
and 6, or 5 and 12, or 8 and 7½, wh
laſt is moſt convenient. A

8)96(12 if you take all the Pinions
8)64(8 the work will ſtand as in t
8)60(7⅝ Margin.

30 According to this compu
tion, the Great-wheel will
about once in 12 hours,
ſhew the hour, if you pleaſe: the Seco
wheel once in an hour, to ſhew the
nutes; and the Swing-wheel once in a
nute, to ſhew the ſeconds.

T

Thus I have endeavour'd with all poſſible plainneſs, to unravel this moſt myſterious, as well as uſeful part of Watch-work. In which, if I have offended the more learned Reader, by unartificial terms, or multitude of words, I deſire the fault may be laid upon my earneſt intent to condeſcend to the meaneſt capacity.

SECT. III.

To Calculate the Striking part of a Clock.

§ 1. ALtho this part conſiſts of many Wheels and Pinions, yet reſpect needs to be had only to the *Count-wheel*, *Striking-wheel*, and *Detent-wheel:* which move round in this proportion; The Count-wheel moveth round commonly once in 12, or 24 hours. The Detent-wheel moves round every ſtroke the Clock ſtriketh, ſometimes but once in two ſtrokes. From whence it follows,

1. That as many Pins as are in the Pin-wheel, ſo many turns hath the Detent-wheel, in one turn of the Pin-wheel. Or (which is the ſame) the Pins of the

Pin-wheel are the Quotient of that Wheel, divided by the Pinion of the Detent-wheel. But if the Detent-wheel moveth but once round in two ſtrokes of the Clock, then the ſaid Quotient is but half the number of Pins.

2. As many turns of the Pin-wheel as are required to perform the ſtrokes of 12 hours (which are 78) So many turns muſt the Pinion of Report have, to turn round the Count-wheel once. Or thus: Divide 78 by the number of Striking-pins, and the Quotient thereof ſhall be the Quotient of the Pinion of Report. All this is, in caſe the Pinion of Report be fixed to the arbor of the Pin-wheel, as is very commonly done.

All this I take to be very plain: or if it be not, the example in the Margin will clear all difficulties. Here

8)48(6 — the Locking-wheel is 48
6)78(13 pins — the Pinion of Report is 6
6)60(10 — the Pin-wheel is 78, the
6)48(8 — Striking-pins are 13. And ſo of the reſt. I need only to remark here, that 78 being divided by the 13 pins, gives 6 which is the Quotient of the Pinion

of Report: as was before hinted.

As for the *Warning-wheel*, and *Flying-Pinion*, it matters little what numbers they have, their uſe being only to bridle the rapidity of the motion of the other Wheels.

Beſides the laſt obſervation, there are other ways to find out the Pinion of Report, which will fall under the next §.

§ 2. Theſe following Rules will be of great uſe in this part of Calculation, *viz.*

Rule 1. As the number of turns of the Great-wheel, or Fuſy;

. To the days of the Clock's continuance:

:: So is the number of ſtrokes in 24 hours, *viz.* 156,

. To the ſtrokes in one turn of the Fuſy, or Great-wheel.

Rule 2. As the number of ſtrokes in 24 hours, which are 156,

. To the ſtrokes in one turn of the Fuſy, or Great-wheel,

:: So are the turns of the Fuſy, or Great-wheel,

. To the days of the Clock's continuance, or going.

Rule 3. As the ſtrokes in one turn of the Fuſy;

. To the ſtrokes of 24 hours, *viz.* 156.
:: So is the Clock's continuance,
. To the number of turns of the Fuſy, or Great-wheel.

Theſe two laſt Rules are of no great uſe (as the firſt is) but may ſerve to correct your work, if need be, when in breaking your Strokes into Quotients (of which preſently) you cannot come near the true number, but a good many ſtrokes are left remaining. In this caſe, by Rule 2. you may find whether the continuance of your Clock be to your mind. And by Rule 3, you may enlarge or diminiſh the number of turns for this purpoſe. The praxis hereof will follow by and by.

The 2 following Rules are to find fit numbers for the Pinion of Report, and the Locking-wheel, beſides what is ſaid before § 1. Inference 2.

Rule 4. As the number of Strokes in the Clock's continuance, or in all its turns of the Fuſy,
. To the turns of the Fuſy,
:: So are the Strokes in 12 hours, which are 78,
. To the Quotient of the Pinion of Report, fixed upon the arbor of the Great-wheel.

But

But if you would fix it to any other Wheel, you may do it thus, as is before hinted, *viz.* § 1. Infer 2.

Rule 5. First, find out the number of Strokes, in one turn of the Wheel you intend to fix your Pinion of Report upon (which I shall shew you how to do in the following §.) Divide 78 by this number, and the number arising in the Quotient, is the Quotient of the Pinion of Report.

Or thus. Take the number of Strokes in one turn of the Wheel, for the number of the Pinion of Report, and 78 for the Count (or Locking) wheel, and vary them to leſſer numbers, by Sect. 2. § 5. of this Chapter.

Rule 6. The foregoing Rules are of greateſt uſe, in Clocks of a larger continuance; altho, where they can be applied, they will indifferently ſerve all. But this Rule (which will ſerve larger Clocks too) I add chiefly for the uſe of leſſer Pieces, whoſe continuance is accounted by hours.

The Rule is to find the Strokes in the Clock's continuance, *viz.* As 12, is to 78 :: So are the hours of the Clocks continuance,

ance, To the number of Strokes in that time.

This Rule (I ſaid) may be made uſe of for the largeſt Clock; but then you muſt be at the trouble of reducing the Days into Hours Whereas the ſhorteſt way is to Multiply the ſtrokes in one turn of the Great-wheel, by the number of Turns. Thus in an 8 day piece the Strokes in one turn are 78. Theſe multiplied by 16, the turns, produce 1248; which are the Strokes in the Clock's continuance. If you work by the foregoing Rule, the hours of 8 days are 192. Then ſay, 12. 78 :: 192. 1248.

§ 3. In this Paragraph, I ſhall ſhew the uſe of the preceding Rules, and by examples make all plain that might ſeem obſcure in them.

I begin with ſmall Pieces: of which but briefly. And firſt, having pitched upon the number of turns, and the continuance, you muſt find, by the laſt Rule, how many Strokes are in its continuance. Then divide theſe Strokes by the number of turns, and you have the number of Striking-pins. Or divide by the number of Pins, and you have the number of Turns. Thus

Thus a Clock of 30 hours, with 15 turns of the Great-wheel, hath 195 ſtrokes. For by the laſt Rule, 12. 78 :: 30. 195. Divide 195 by 15, it gives 13 for the Striking-pins. Or if you chuſe 13 for your number of Pins, and divide 195 by it, it gives 15, for the number of turns, as you ſee in the Margin.

15)195(13
13)195(15

As for the Pinion of Report, and the reſt of the Wheels, enough is ſaid in the § 1.

But ſuppoſe you would calculate the numbers of a Clock of much longer continuance, which will neceſſitate you to make your Pin-wheel further diſtant from the Great-wheel, you are to proceed thus: Having reſolved upon your turns, you muſt find out the number of ſtrokes in one turn of the Great-wheel, or Fuſy, by § 2. Rule 1. Thus in an 8 day piece, of 16 turns, 16. 8 :: 156. 78. So in a piece of 32 days, and 16 turns, 16. 32 :: 156. 312. Theſe ſtrokes ſo found out, are the number which is to be broken into a convenient parcel of Quotients, thus;

Firſt reſolve upon your number of Striking

king-pins: divide the laſt named number by it: The quotient ariſing hence, is to be one, or more quotients, for the Wheels and Pinions. As in the laſt example, Divide 78 by 8 (the uſual pins in an 8 day piece) and the quotient is 9¾ which is a quotient little enough. So in the Month-piece: if you take your Pins 8, divide 312 by it, the quotient is 39. Which being too big for one, muſt be broken into two quotients, for Wheels and Pinions, or as near as can be: which may be 7 and 5, or 6 and 6½. The latter is exactly 39, and may therefore ſtand: as you ſee is done in the Margin.

```
12)65(6½
 8)48(6
 6)48(8 pins
```

The quotients being thus determined and accordingly the Wheels and Pinions as you ſee; the next work is to find a quotient for the Pinion of Report, to carry round the Count (or Locking) wheel once in 12 hours, or as you pleaſe. If you fix your Pinion of Report on the Great-wheel arbor, you muſt operate by the Rule 4. of the laſt paragraph. As in the laſt example in the Month-piece: by Rule 6. before, the ſtrokes in the conti-

ance are 4992. Then by Rule 4 ſay, 4992. 16 :: 78. $\frac{4992}{1248}$; or thus, 4992)1248. The firſt of which two numbers is the Pinion, the next is the Wheel. Which being too large, may be varied to $\frac{1}{3}$ or 36)9; or to $\frac{1}{8}$ or 24)6, by *Sect.* 2 § 5. before. V. Sect. 1. §. 3.

Theſe numbers being not the uſual numbers of a Month-piece, but only made uſe of by me, as better illuſtrating the foregoing Rules; I ſhall therefore, for the fuller explication of what has been ſaid, briefly touch upon the calculation of the more uſual numbers. They commonly encreaſe the number of Striking-pins, and ſo make the Second-wheel the Striking-wheel. Suppoſe you take 24 Pins; Divide 312 by it, and the Quotient is 13.

8)104(13
6) 72(12. 24 pins

Which is little enough for one Quotient; and may therefore ſtand as you ſee is done in the Margin: where the Quotient of the firſt Wheel is 13. In the ſecond Wheel of 72 teeth, are the 24 pins, altho its quotient is but 12, becauſe the Hoop-wheel is double, and goes round but once in two ſtrokes of the Pin-wheel.

The Pinion of Report here, is the ſame with the laſt, if fixed upon the arbor of the Great-wheel. But if you fix it on the arbor of the Second, or Pin-wheel, its quotient then is found by § 1. Inſer. 2. or by § 2. Rule 5. *viz.* Divide 78 by 24, and the number ariſing in the quotient, is the quotient of the Pinion of Report, which is 3 ¼. The Pinion of Report then being 12, the Count-wheel will be 39, as in the Margin.

12)39(3¼

To perfect the Reader in this part of Calculation, I will finiſh this Section with the calculation of a Year-piece of Clock-work. The Proceſs whereof is the ſame with the laſt, and therefore I may be more brief with this, except where I have not touched upon the foregoing Rules.

We will chuſe a piece to go 395 days with 16 turns, and 26 Striking-pins. By § 2. Rule 1. there are 3851 ſtrokes in one turn of the Great-wheel. For 16. 395 :: 156. 3851. This laſt number divided by the 26 Pins, leaves 148 in the quotient, to be broken into two or more quotients, for Wheels and Pinions. Theſe quotients may be 12 and 12; which multiplied, makes

10)120(12
8) 96(12
78|26 pins

makes 144, which is as near as can well be, to 148. The work thus far contrived, will ſtand as you ſee in the Margin.

Before you go any further, you may correct your work, and ſee how near your numbers come to what you propoſed at firſt, becauſe they did not fall out exact. And firſt, for the true continuance of your Clock: *If you multiply* 12, 12, *and* 26 (i. e. *the Quotients un'o the Striking-pins, and thoſe Pins*) *you have the true number of Strokes, in one turn of the Great-wheel:* Which, in this example, make 3744. For 12 times 12, is 144; and 26 times that, is 3744. (This Direction I would have noted, and remembered, as a Rule uſeful at any time to diſcover the nature of any piece of Clock-work.) Having thus the true number of Strokes deſired, by § 2. Rule 2. you may find the true Continuance to be only 384 days. For 156. 3744 :: 16. 384. If this Continuance doth not pleaſe you, you may come nearer to your firſt propoſed number, of 395 days, by a ſmall encreaſe of

the number of Turns; according to § 2. Rule 3. *viz.* by making your turns almoſt 16 ½. For 3744. 156 :: 395. 16½ almoſt.

Laſtly, For the Pinion of Report, if you fix it upon the Great-wheel, it will require an exceſſive number: if you fix it upon the Pin-wheel (which is uſual) then by § 2. Rule 5, the quotient is 3; and the Pinion of Report being 13, the Count-wheel will be 39; as you ſee in the Margin.

13)39(3

But for the better exerciſing the Reader, let us fix it upon the Spindle of the Second-wheel 96. Its quotient is 12, which multiplied by 26 (the pins) produceth 312; which are the Strokes in one turn of that Second-wheel. Then by § 2. Rule 5, Divide 78 by 312, *i. e.* Set them as a Wheel and Pinion thus, 312)78, and vary them to leſſer numbers (by Sect. 2. § 5.) *viz.* 36/9, or to 24/6, or the like.

I think it needleſs to ſay any thing of Pocket-clocks, whoſe calculation is the very ſame, with what goes before.

The

That the unlearned Reader may not think any thing going before difficult, I need only to adviſe him, to look over the working of the Rule of Proportion, in Sect. 2. § 4. For I think all will be plain, if that be well underſtood.

SECT. 4.

Of Quarters and Chimes.

THe Reader will expect that I ſhould ſay ſomewhat concerning Quarters and Chimes: but becauſe there is little, but what is purely mechanical in it, I ſhall ſay the leſs, and leave the Reader to his own invention.

§ 1. The *Quarters* are generally a diſtinct part from the Clock-part, which ſtriketh the Hour.

The *Striking-wheel* may be the Firſt, Second, or &c. Wheel, according to your Clock's continuance. Unto which Wheel you may fix the Pinion of Report.

The *Locking-wheel* muſt be divided (as other Locking-wheels) into 4,8, or more unequal parts, ſo as to ſtrike the Quarter, and lock at the firſt Notch; the half-hour, and lock

lock at the ſecond Notch, &c. And in doing this, you may make it to chime the Quarters, or ſtrike them upon two Bells, or more.

'Tis uſual for the Pin-wheel, or the Locking-wheel, to unlock the Hour-part in theſe Clocks; which is eaſily done by ſome jogg or Latch, at the end of the laſt Quarter, to liſt up the Detents of the Hour-part.

If you would have your Clock ſtrike the Hour, at the Half-hour, as well as whole Hour, you muſt make the Locking-wheel of the Hour-part double: *i. e.* it muſt have two Notches of a ſort, to ſtrike 1, 2, 3, 4, &c. twice apiece.

§ 2. As for *Chimes*, I need ſay nothing of the Lifting-pieces and Detents, to lock and unlock; nor of the Wheels to bridle the motion of the Barrel. Only you are to obſerve, that the Barrel muſt be as long in turning round, as you are in Singing the Tune it is to play. As for the *Chime-Barrel*, it may be made up of certain Barrs, that run athwart it, with a convenient number of holes punched in them, to put in the Pins, that are to draw each Hammer. By this means, you may change the

the Tune, without changing the Barrel. This is the way of the *Royal Exchange* Clock in *London*, and of others. In this caſe, the Pins or Nuts, which draw the Hammers, muſt hang down from the Barr, ſome more, ſome leſs, and ſome ſtand upright in the Barr: the reaſon whereof is, to play the Time of the Tune rightly. For the diſtance of each of theſe Barrs, may be a Semi-brief, or *&c.* of which hereafter.

But the moſt uſual way is, to have the Pins that draw the Hammers, fixed on the Barrel. For the placing of which Pins, you may make uſe of the Muſical Notes, or proceed by the way of Changes on Bells, *viz.* 1, 2, 3, 4, *&c.* The firſt being far the better way, I ſhall ſpeak of that chiefly, eſpecially becauſe the latter will fall in to be explained with it.

And firſt, you are to obſerve what is the Compaſs of your Tune, or how many Notes or Bells there are from the higheſt to the loweſt: and accordingly you muſt divide your Barrel from end to end. Thus in the examples following, each of thoſe Tunes are 8 notes in compaſs; and accordingly the Barrel is divided into 8 parts.

parts. These Divisions are struck round the Barrel, opposite to which are the Hammer-tails.

I speak here, as if there was only one Hammer to each Bell, that the Reader may more clearly apprehend what I am explaining. But when two Notes of the same sound come together in a Tune, there must be two Hammers to that Bell, to strike it. So that if in all the Tunes you intend to Chime, of 8 notes compass, there should happen to be such double Notes on every Bell, instead of 8, you must have 16 Hammers: and accordingly you must divide your Barrel, and strike 16 strokes round it opposite to each Hammer-tail. Thus much for dividing your Barrel from end to end.

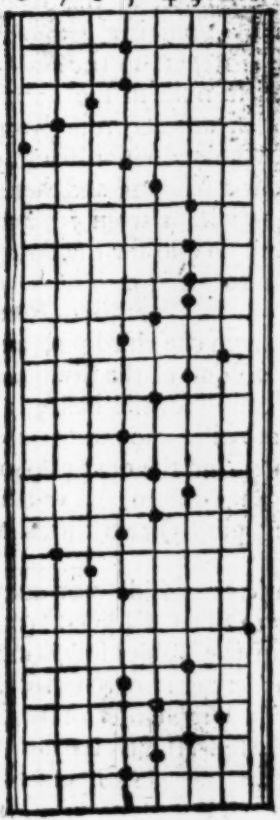
In the next place, you are to divide it (round about) into as many divisions, as there are Musical Barrs, Semibriefs, Minums, *&c.* in your Tune. Thus the 100th Psalm-tune hath 20 Semibriefs; the Song-tune following, hath 24 Barrs of triple time: and accordingly their Barrels are divided. Each division therefore of the 100th Psalm Barrel is a Semibrief, and of the Song-tune 'tis three crotchets.

And

And therefore the intermediate Spaces ſerve for the ſhorter notes: as, one third of a diviſion, is a Crotchet, in the Song-tune. One half a diviſion, is a Minum; and one quarter a Crotchet, in the Pſalm-tune. Thus the firſt note in the 100th Pſalm, is a Semibrief, and accordingly on the Barrel, 'tis a whole diviſion from 5 to 5. The ſecond is a Minum, and therefore 6 is but half a diviſion from 5; and ſo of the reſt. And ſo alſo for the Song-tune, which is ſhorter time: The two firſt notes being Quavers, are diſtant from one another, and from the third pin, but half a third part of one of the diviſions. But the two next pins (of the bell 3, 3) being Crotchets, are diſtant ſo many third parts of a diviſion. And the next pin (of the bell 1) being a Minum, is diſtant from the following pin (4) two thirds of a diviſion.

From what hath been ſaid, you may conceive the ſurface of a Chime-barrel, to be repreſented in the Tables following, as ſtretched out at length: or (to ſpeak plainer) that if you wrap either of theſe Tables round a Barrel, the Dotts in the Table, will ſhew the places of the

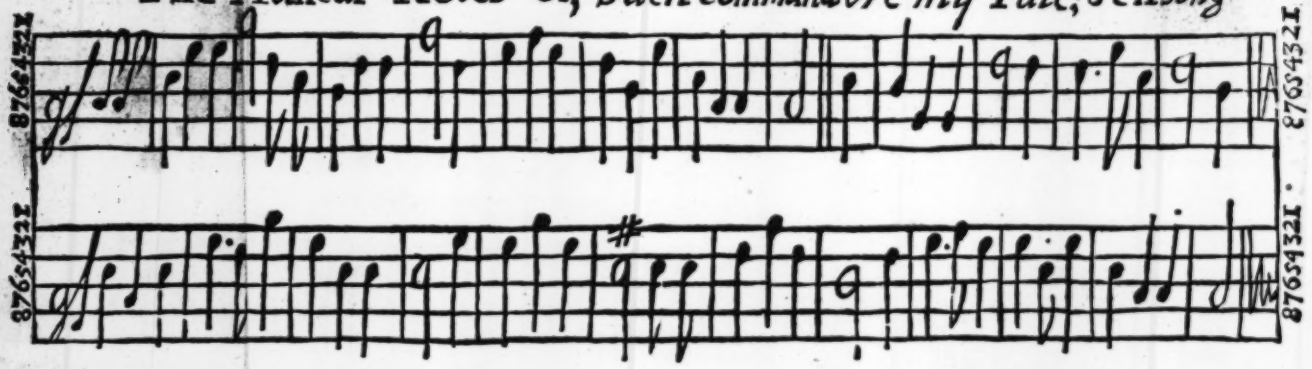
A Table of Chimes to the 100 Pſalm.



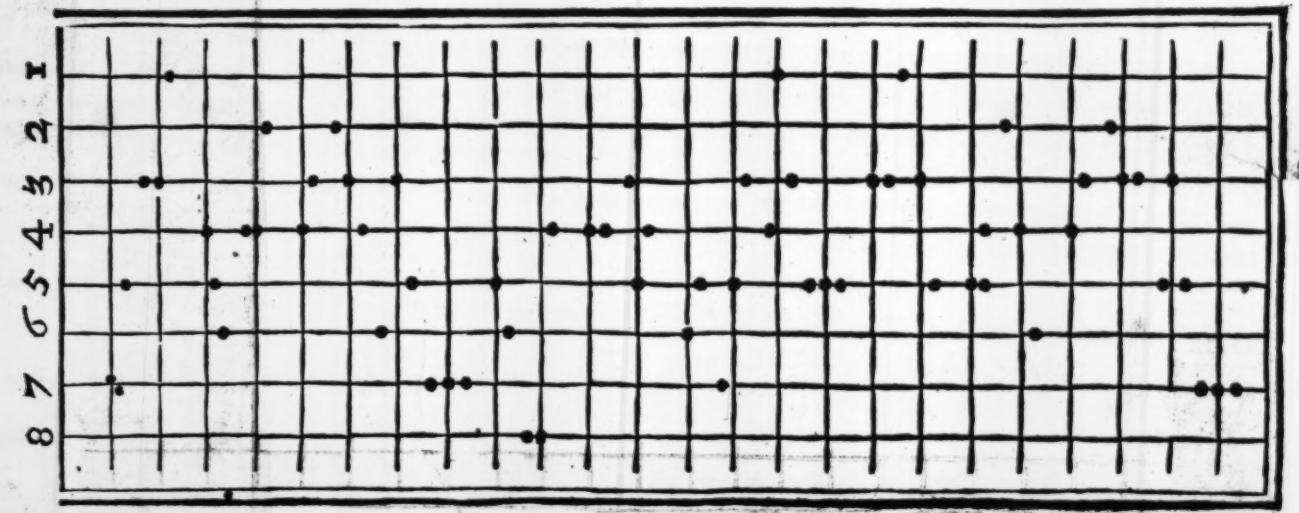
The Muſical Notes of Pſalm 100.

The Musical Notes of Psalm 100.

The Musical Notes of, *Such Command o're my Fate, &c* A song



The Chimes of the Song, *Such Command o're my Fate, &c.*



To be inserted between notes 22 and 23

Pins, to be ſet on the Barrel.

You may obſerve in the Tables, that from the end of each Table to the beginning, is the diſtance of two, or near two diviſions: which is for a Pauſe, between the end of the Tune, and its beginning to Chime again.

I need not ſay, that the Dotts running about the Tables, are the places of the Pins that play the Tune.

If you would have your Chimes compleat indeed, you ought to have a ſet of Bells, to the Gamut notes; ſo as that each Bell having the true ſound of Sol, La, Mi, Fa, you may play any Tune, with its Flats and Sharps. Nay, you may by theſe means, play both the Baſs and Treble, with one Barrel.

If any thing going before appears gibberiſh, I can't help it, unleſs I ſhould here teach the skill of Muſick too.

As to ſetting a Tune upon the Chime-barrel from the number of Bells, *viz.* 1, 2, 3, 4, I ſhall here give you a ſpecimen thereof.

Such Command o're my Fate, in numbers.

775, 3, 3, 1. 4, 5, 6, 4, 4, 2.
4, 3, 2, 3, 4, 6, 3, 5, 7, 7, 7. ||
5, 6, 8, 8, 4. 4, 4; 3, 5, 4.
6, 5, 7, 5, 3; 41, 3, 5, 5, 5.
3, 3, 1, 3, 5. 554, 2, 4, 6.
4, 3; 23, 3; 53, 5, 7, 7, 7.

Note, In these numbers, a Comma [,] signifies the note before it, to be a Crotchet. A prick'd Comma, or Semi-colon [;] denoteth a prick'd Crotchet. And a Period [.] is a Minum. Where no punctation is, those Notes are Quavers.

I shall only add further, that by setting the Names of your Bells at the head of any Tune (as is done in the Tables before) you may easily transfer that Tune, to your Chime-barrel, without any great skill in Musick. But observe, that each line in the Musick, is three notes distant; *i. e.* there is a Note between each line, as well as upon it: as is manifest by inspecting the Tables.

SECT.

SECT. 5.

To Calculate any of the Celeſtial Motions.

The Motions I here chiefly intend, are the Day of the Month, the Moons age, the Day of the Year, the Tides, and (if you pleaſe) the ſlow motion of the Suns *Apogæum*, of the Fixed Stars, the motion of the Planets, *&c.*

§ 1. For the effecting theſe Motions, you may make them to depend upon the Work already in the Movement; or elſe meaſure them by the beats of a Ballance, or Pendulum.

If the latter way, you muſt however contrive a Piece (as before in Watch-work) to go a certain time, with a certain number of turns.

But then to Specificate, or determine the Motion intended, you muſt proceed one of theſe two ways: either,

1. Find how many beats are in the Revolution. Divide theſe beats by the beats in one turn of the Wheel, or Pinion, which you intend ſhall drive the intended Revolution; and the Quotient ſhall be the

the number to perform the ſame. Which, if too big for one, may be broken into more Quotients. Thus, if you would repreſent the Synodical Revolution of the Moon, which is 29 days, 12 ¾ hours) with a Pendulum that ſwings Seconds, the Movement to go 8 days, with 16 turns of the Fuſy, and the Great-wheel to drive the Revolution. Divide 2551500 (the Beats in 29 days 12 ¾ hours) by 43200 (the Beats in one turn of the Great-wheel) and you will have 59 in the Quotient: which being too big for one, may be put into two Quotients. Or

2. You may proceed as is directed before, in the Section of Calculating Watch-work, *viz.* Chuſe your Train, turns of the Fuſy, Continuance, *&c.* And then inſtead of finding a Quotient for the Pinion of Report, find a number (which is all one as a Pin. of Report) to Specificate your Revolution, by this following Rule.

Ch. 2. Sect. 2. § 7.

Rule. As the Beats in one turn of the Great-wheel. To the Train :: So are the Hours of the Revolution, To the Quotient of the Revolution.

Thus to perform the Revolution of *Saturn* (which is 29 years, 183 days) with a

16

16 hour Watch, of 26928 Beats in one turn of the Fuſy, and 20196, the Train: the quotient of the Revolution, will be 193824. For, As 26928, To 20196:: So 258432 (the Hours in 29 y. and 183 d.) To 193824. Note here, That the Great-wheel Pinion is to drive the Revolution work.

But if you would have the Revolution to be driven by the Dial-wheel, and the Work already in the Movement (which in great Revolutions, is for the moſt part, as nice as the laſt way, and in which I intend to treat of the particular Motions) in this caſe, I ſay, you muſt firſt know the Days of the Revolution. And becauſe the Dial-wheel goeth round twice in a day, therefore double the number of the days in the Revolution, and you have the number of turns of the Dial-wheel in that time. This number of turns is what you are to break into a convenient number of quotients, for the Wheels and Pinions; as ſhall be ſhewed in the following examples.

§ 2. A Motion to ſhew the *Day of the Month.*

The

Oughtred. § 26.

The days in the largeſt Month are 31. Theſe doubled are 62, which are the turns of the Dial-wheel, which may be broken into theſe two quotients $15\frac{1}{2}$ and 4; which multiplied together make 62. Therefore chuſing your Wheels and Pinions, as hath been directed in the former Sections, your work is done. The Wheels and Pinions may be, as you ſee done in the Margin.

4)62(15½
5)20(4

Or if a larger Pinion than one of 5 be neceſſary, by reaſon it is concentrick to a Wheel, you may take 10 for the Pinion, and 40 for the Wheel, as in the Margin.

4)62(15½
10(40(4

The work will lye thus in the Movement, *viz.* Fix your Pinion 10, concentrical to the Dial-wheel (or to turn round with it upon the ſame Spindle.) This Pinion 10 drives the Wheel 40: which Wheel has the Pinion 4 in its center, which carrieth about a Ring of 62 teeth, divided on the upper ſide into 31 days.

Or, you may, without the trouble of many Wheels, effect this motion; *viz.* By a Ring divided into 30 or 31 days, and as many Fangs or Teeth, like a Crown-

wheel

wheel teeth, which are caught and puſhed forward once in 24 hours, by a pin in a Wheel, that goeth round in that time. This is the uſual way in the Royal Pendulums, and many other Clocks; and therefore being common, I ſhall ſay no more of it.

§ 3. *A Motion to ſhew the age of the Moon.* Id. ib.

The Moon finiſheth her courſe, ſo as to overtake the Sun, in 29 days, and a little above an half. This 29 ½ days (not regarding the ſmall exceſs) makes 59 twelve hours, or turns of the Dial-wheel, which is to be broken into convenient quotients: which may be 5,9 and 10 as in the firſt example; or 14¾ and 4, as in the ſecond example in the Margin. So that if you fix a Pinion of 10 concentrical with your Dial-wheel, to drive a Wheel of 40 (according to the laſt example) which Wheel 40 drives a Pinion 4, which carries about a Ring, or Wheel of 59 teeth, divided on the upper ſide into 29 ½, 'twill ſhew the Moons age.

10)5,9(:9 4)59(14¾
4)40(10 10)40(4

Id. lb.

§ 4. *A Motion to shew the day of the Year, the Sun's place in the Ecliptick, Sun's Rising or Setting, or any other annual motion of 365 days.*

The double of 365 is 730, the turns of the Dial-wheel in an year: which may be broken into these quotients, *viz.* 18 ¼, and 10, and 4, according to the first example; or 18 ¼, 8, and 5, according to the second. So that a Pinion of 5 is to lead a Wheel of 20; which again by a Pinion of 4, leadeth a Wheel of 40; which thirdly, by a Pinion of 4, carrieth about a Wheel, or Ring of 73, divided into the 12 months, and their days; or into the 12 signs, and their degrees; or into the Sun's Rising and Setting, *&c.* For the setting on of which last, you have a Table in Mr. *Oughtred's Opuscula.*

4)73(18¼ 4)40(10 5)20(4

4)73(18¼ 4)32(8 4)20(5

Autom. § 35. Id. ib.

§ 5. *To shew the Tides at any Port.*

This is done without any other trouble, than the Moon's Ring (before mentioned § 3.) to move round a fixed circle, divided into twice 12 hours, and numbered the contrary way to the age of the Moon.

To

To ſet this to go right, you muſt find out at what Point of the Compaſs the Moon makes full Sea, at the place you would have your Watch ſerve to. Convert that point into hours, allowing for every point North or S. loſt 45′ of an hour. Thus at *London-bridge* 'tis vulgarly thought to be high Tide, the Moon at N. E. and S. W, which are 4 Points from the N. and S. Or you may do thus: by Tide-tables learn how many hours from the Moon's Southing, 'tis High-water. Or thus; find at what hour it is High-water, at the Full or Change of the Moon: as at *London-bridge*, the full Tide is commonly reckoned to be 3 hours from the Moon's Southing; or at 3 of clock at the Full and Change. The day of Conjunction, or New-Moon, with a little ſtud to point, being ſet to the hour ſo found, will afterwards point to the hour of full Tide.

This is the uſual way: but it being always in motion, as the Tides are not, a better way may be found out, *viz.* By cauſing a Wheel, or Ring to be moved forward, only twice a day, and to keep time (as near as can be) with Mr. *Flamſteed*'s moſt correct Tables. But this I

ſhall commit to the Readers contrivance, it being eaſie, and more of curioſity than uſe.

§ 6. *To Calculate Numbers, to ſhew the Motion of the Planets, the Slow Motion of the Fixed Stars, and of the Sun's Apogeum*, &c.

Having ſaid enough before that may be applied here, and they being only curioſities, ſeldom put in practice, I ſhall not therefore trouble the Reader, or ſwell my Book with ſo many words, as would be required to treat of theſe Motions diſtinctly, and compleatly.

Only thus much in general. Knowing the years of any of theſe Revolutions, you may break this number into quotients; if you will make the Revolution to depend upon the year's Motion; which is already in the Movement, and deſcribed § 4. before. Or if you would have it depend upon the Dial-wheel, or upon the Beats of a Pendulum, enough is ſaid before to direct in this matter.

In all theſe ſlow motions, you may ſomewhat ſhorten your labour, by endleſs Screws to ſerve for Pinions, which are but as a Pinion of one tooth.

Sir

Sir *Jonas Moor's* account of his large ſphere going by Clock-work, will ſufficiently illuſtrate this paragraph. In this ſphere, is a Motion of 17100 years, for the Sun's *Apogeum*, performed by ſix Wheels, thus, as Sir *Jonas* relates it; 'For the Great-wheel fixed is 96, a Spindle-wheel of 12 bars turns round it 8 'times in 24 hours, that is, in 3 hours; 'after theſe, there are four Wheels, 20, '73, 24, and 75, wrought by endleſs 'Screws that are in value but one: there-'fore 3, 20, 73, 24, and 75 multiplied to-'gether continually, produceth 7884000 'hours, which divided by 24 gives '3285000 days, equal to 900 years. 'Now on the laſt wheel 75 is a pinion of '6, turning a great Wheel, that carrieth the '*Apogeum* number 114: and 114 divided 'by 6, gives 19 the quotient: and 900 'times 19 is 17100 years. Mar. Com. P. 117. V. Sect. 1 § 4, 5.

Thus I have, with all the perſpicuity I could, led my Reader through the whole Art of Calculation, ſo much of it at leaſt, that I hope he will be maſter of it all; not only of thoſe motions, which I have particularly treated about, but of any other not mentioned: Such as the Revolution of

of the Dragons Head and Tail, whereby the Eclipſes of the Sun and Moon are found, the Revolution of the ſeveral Orbs, according to the *Ptolemaick* Syſtem, or of the celeſtial bodies themſelves, according to better Syſtems, with many other ſuch curious performances, which have made the Sphere of *Archimedes* of old famous: and ſince him, that of *William* of *Zeland*, and another of *Janellus Turrianus* of *Cremona*, mentioned by *Cardan*: and of late, that elaborate piece of Mr. *Watſon*, late of *Coventry*, now of *London*, in her late Majeſties Cloſet.

De Subtil. l. 17.

CHAP. III.

To alter Clock-work, or convert one Movement into another.

THis Chapter I deſign for the uſe of ſuch, as would convert old Ballance Clocks into Pendulums, or would make any old work ſerve for the tryal of new motions, or would apply it to any other ſuch like uſe. §. 1.

§ 1. To do this, you may draw a Scheme of your old work: and ſo you will ſee what Quotients you have, and what you will want. To do all which, there are ſufficient inſtructions in the preceding Chapter. A few inſtances will make all plain.

§ 2. Let us chuſe for inſtance an old Ballance clock to be turned into a Pendulum of 6 inches. The old work is, The Great-wheel 56, the Pinion 7; the next Wheel 54, the Pinion 6; the Crown-wheel 19, &c. The Scheme of this work is in the Margin. The Quotients and Crown-wheel and 2 Pallets multiplied together continually, produce 2736, which are the Strokes of the Ballance, in one turn of the Great-wheel, by Sect. I. § 4, 5. of the laſt Chapter. And by the Quotient of the Dial-wheel (which is 12) it appears, that the Great-wheel goeth round once in an hour. Or you may find the Beats in an hour, by § 5. laſt cited. Having thus found the Beats in an hour, of the old work, you muſt next find the Beats in an hour, of a 6 inches Pendulum; which you may do by

4)48(12
7)56(8
6)54(9
19

Horol. Diſ. p. 54. Chap. 5. § 4. following; or by Mr. *Smith's* Tables, according to whom the number is 9368. Divide this by 2736, and you have the Quotient, which is to be added to the Scheme of the old work. This Quotient is 3 and near $\frac{1}{2}$, as you ſee in the Margin.

2736)9368(3½

The work thus altered, will ſtand as you ſee in the Margin, *viz.* a Pinion 6, and a Contrate-wheel 21, muſt be added.

4)48(12
7)56(8
6)54(9
6(21:(3½
19

According to this way, the old work will ſtand as before, only the Crown-wheel muſt be inverted.

§ 3. But becauſe the Crown-wheel is too big for the Contrate-wheel (which is unſeemly) therefore it will be beſt, to make both the Contrate, and Crown-wheels new; and encreaſe the number of the Contrate-wheel, but diminiſh that of the Crown-wheel. To do which, pitch upon ſome convenient number for the Crown-wheel. Multiply all the Quotients, and this new Crown-wheel number, as before; and divide 9368 by it. As,

product

Suppoſe you pitch upon 11 for the Crown-wheel: if you multiply 8, 9 and 11, the Product is 792; which multiplied by the 2 Pallets, makes 1584, which are the Beats in one turn of the Great-wheel, or in an hour. Divide 9368 by it, and you have near 6 for the Quotient of your Contrate-wheel. The work thus ordered, will ſtand as in the Margin.

V. Sect. 1. § 6.

4)48(12
7)56(8
6)54(9
6)36(6
——
11

If you would correct your work, to find the true number of Beats in an hour, &c. you muſt proceed, as is ſhewn Sect. 2. § 6, and latter end of § 7. of the laſt Chapter.

§ 4. But ſuppoſe you have a mind to change the former old Watch, into a 30 hour piece, and to retain the old Ballance-wheel (which may be often done:) in this caſe, you muſt add a Contrate-wheel, and alter the Pinion of report. For the Contrate-wheel, chuſe ſuch a Quotient, as will beſt ſuit with the reſt of your work; and then multiply all your Quotients, Crown-wheel and 2 Pallets together, and ſo find the number of turns in the Great-wheel, as before. Then ſay by

Sect. 2. § 6. part 5. before, As the Beats in one turn of the Great-wheel, To the Beats in an hour:: So are the hours of the Dial, To the quotient of the Pinion of Report.

Thus in the old work before; to the old quotients 8 and 9, you may add another of 8, for the Contrate-wheel. Thoſe multiplied, as was now directed, make 21888, for the Beats in one turn of the Great-wheel. And then for the quotient of the Pinion of Report, ſay in numbers thus, 21888. 9368 :: 12.5.

6)30(5
7)56(8
6)54(9
6)48(8
—
19

The quotient for the Pinion of Report is ſomewhat more than 5, which overplus may be neglected, as you ſee by the Scheme of the whole work in the Margin.

If you deſire to know what number of turns, the Fuſy muſt have in this work; Say by the laſt quoted §, part 1, in numbers thus, 21888.9368 :: 30.13 almoſt. So that near 13 turns will do.

If you would correct your work, to know the exact Beats, &c. you are referred to directions in the end of the laſt paragraph. § 5.

§ 5. I ſhall add but one thing more, to what hath been ſaid in this Chapter, and that is, to change the Striking part of this old Movement, into a 30 hour piece.

A Scheme of the old work is in the Margin.

4)39(9¾
7)56(8 pins
6)54(9
6)48(8

And to alter it, the beſt way is, to double the number of Striking pins, making the 8, ſixteen pins: and the Hoop of the Detent-wheel double, that the Pin-wheel may ſtrike two ſtrokes, in its going round once.

The greateſt inconvenience here, will be to bridle the rapidity of the Strokes; becauſe a quotient of (2 only, added to the old work, will be ſufficient for this purpoſe: which being an inconvenient number, 'twill be neceſſary to be content with the old numbers, or make more Wheels and Pinions new, than may be thought worth the while.

If you would find what number of turns, the Fuſy will require; you muſt find how many Strokes are in 30 hours, by Sect. 3. § 2. R. 6. before. Theſe are 195; which divided by the 16 Pins,

gives ſomewhat more than 12 turns of the Fuſy.

Laſtly, for the Pinion of Report, you muſt purſue the directions in the laſt quoted place, R. 5.

5)24(4⅘
7)56(8. 16 pins
6)54(9
6)48(8

The work thus altered, will ſtand as in the Margin.

CHAP. IV.

To ſize the Wheels and Pinions, or proportion them to each other, both Arithmetically and Mechanically.

§ 1. FOr the exact and eaſie moving of the Wheels and Pinions together, it is neceſſary that they ſhould fit each other, by having their teeth and leaves of the ſame wideneſs, or near of the ſame wideneſs. For many do make the

the Leaves of the Pinion narrower than the Teeth of its Wheel, by reaſon of their running deep in each other; which is as if the Diameters of the Wheel and Pinion were leſs. But this I leave to thoſe, whoſe practice and obſervations are greater than mine in theſe matters.

§ 2. To make the Teeth of a Wheel and Pinion alike, the way *Arithmetically* is thus, Firſt you muſt find the Circumference of your Wheel and Pinion; which you may beſt do by the Rule of Three (ſo often made uſe of before) the Rule is thus, as 7 is to 22 :: ſo is the Diameter to the Circumference. Or more exactly thus, as 1, is to 3,1416 :: So Diam. to Circum.

Suppoſe you have a Wheel of 2 inches diameter, and 60 Teeth, and would fit to it a Pinion of 6 Leaves. Firſt 7 22::2.6,3. The circumference of the Wheel, is then 6 inches, and 3 tenths of an inch. Then ſay, as the Teeth of the Wheel, to the circumference of it:: So are the Leaves of the Pinion, to the circumference thereof. In numbers thus 60. 6,3 :: 6 .63. The Pinion then is 63 hundredth parts of an inch round. Sir *J. Moor* Mat. Com. R. 5.

Now

Now to find the Diameter, 'tis but the reverſe of the former Rule, *viz.* As 22. to 7:: So the Circumference to the Diameter. In numbers thus, for the foregoing Pinion, 22.7 :: .63..2. The Diameter then of the Pinion muſt be two tenths of an inch, to fit the aforeſaid Wheel of 2 inches diameter.

§ 3. But becauſe this way may be difficult to perſons unacquainted with Decimal Arithmetick, which is very neceſſary here; therefore I ſhall ſet down a way to do it *mechanically*. Having drawn a Circle, divide it into as many parts, as you intend leaves in the Pinion you would ſize. From two of theſe points in the Circle, draw two lines to the Center: to which apply two of the Teeth of your Wheel, guiding them up and down until they touch at the ſame width on theſe Radii. Mark where this agreement is, and a ſmall circle drawn there, will repreſent the circumference of the Pinion ſought after.

CHAP.

CHAP. V.

Of Pendulums.

§ 1. AMong all known Motions, none meaſureth Time ſo regularly, as that of a Pendulum. But yet Watches governed hereby are not ſo perfect, but that they are ſubject to the variations of weather, foulneſs, &c. And the ſhorter, and leſſer the Pendulum is, ſo much the more ſubject ſuch Watches are to theſe annoyances.

There are two ways to obviate theſe inconveniences in ſome meaſure. One way is, to make the Pendulum long, the Bob heavy, and to vibrate but a little way from its ſettlement. Which is now the moſt uſual way in *England*. The other is the contrivance of the ingenious Mr. *Huygens*, which is, to make the upper part of the rod, play between two cheek parts of a Cycloid. Sir *Jonas Moor* ſays, that after ſome time, and charge of Experiments, he

Id. ib. Rule 3. he believes this latter to be the better way. And Mr *Hugens* calls it *admirable.*

If any desire to know how to make those Cycloidal Cheeks, fit to all Pendulums, I refer him to the aforesaid Mr. *Zulichem*'s Book, because I can't shew how to do it, without the trouble of Figures; and this way is much ceased, since the Crown-wheel method (to which it is chiefly proper) is swallowed up by the Royal Pendulums.

De Horol. Oscil. p. 10, 11, 12.

§ 2. Another thing to be remark'd in Pendulums is, That the longer the Vibration is, the slower it is. For if two isochrone Pendulums do move, one the quadrant of a circle, the other not above; or 4 degrees, this latter shall move somewhat quicker than the former. Which is the true reason, why small Crown-wheel Pendulums go faster in cold weather, or when foul, than at other times. Yea, in the best Royal Pendulum, if you put a divided plate behind the Ball, and observe its swings, you may perceive the Vibrations to be sometimes shorter; and that then the Watch doth gain too much. Somewhat also may perhaps be attributed to the rarity or density of the air; which

I have not yet had an opportunity of observing, by comparing with a good Baroscope, the various vibrations of a good Royal Pendulum. But Mr. *Boyl* says, that a Pendulum moveth as long, and as fast in a thick medium, as a thin one; contrary to the opinion of some Naturalists, who think the contrary. His opinion is grounded upon the experiment of a Pendulum vibrating in his air-pump, the air sucked out, and in the open air; wherein was no alteration. *Machina Pneumat. Exp. 26.*

§ 3. For the calculation of all Pendulums, 'tis necessary to fix upon some one, to be as a Standard to the rest. I pitch upon a Pend to vibrate Seconds each stroke.

Mr. *Hugens* lays down the length of a Pend. to swing Seconds to be 3 feet, 3 inches, and 2 tenths of an inch (according to Sir *J. Moor*'s reduction of it to *Engl. sh* measure.) Ibid.

"The Honourable Lord *Bruncker* (saith Sir *Jonas*) "and Mr. *Rook*, found the length "to be 39,25 inches, which a little exceeds "the other: and may be, was justened by "Mr. *Hugens*'s Rule for the Center of Oscillation. For *Mounton*'s Pendulum, that, Ibid.

" vibrate 132 times in a minute, it will be " found likewiſe 8,1 inches, agreeing to " 39,2 inches *Engliſh.* Therefore for cer- " tain 39,2 inches may be called the *Uni-* " *verſal meaſure*, and relied on, to be the " near length of a Pend. that ſhall ſwing " Seconds each vibration.

But foraſmuch as the different ſize of the Ball, will make ſome difference in the length of this Standard Pend., therefore to make this Pend. an *Univerſal meaſure*, to fit all Places and Ages, you muſt meaſure from the Point of Suſpenſion, to the Center of Oſcillation. Which Center is found by this Rule, As the length of the String from the point of Suſpenſion to the center of a round Ball: is to the Semi-diameter of that Ball: : So is that Semi-diameter, to a fourth number. Add two fifths of that fourth number, to the former length, and you have the center of Oſcillation; and thereby the true length of this *Standard Pendulum.*

Hugenius ubi ſupra, p. 141. Sir *J. Moor* ibid.

If it be deſired to fit a Ball of a triangular, quadrangular, or any other form to this Pend, the center of Oſcillation in any of theſe bodies, may be found in the laſt cited book of Mr *Zulichem.*

If

If it be asked, What is the meaning of the Center of Oſcillation? The moſt intelligible anſwer (altho not perfectly true) is, That it is that point of the Ball, at which if you imagine it divided into two parts, by a circle, whoſe center is in the point of Suſpenſion, the lower part of the Ball ſhall be of the ſame weight (or near ſo) with the upper.

§ 4. Having thus fixed a Standard, I ſhall next ſhew how from thence to find the Vibrations, or Lengths of all other Pendulums. Which is done by this Rule, *The ſquares of the Vibrations, bear the ſame Proportion to each other, as their Lengths do.* And ſo contrarywiſe. Wherefore to find the length of a Pend. ſay, As the Square of the Vibrations given: To the Square of 60 (the Standard) :: So is the length of the Standard (*viz.* 39,2) To the length of the Pend. ſought. *Hugen. Mor. ib.*

If by the length, you would find the Vibrations, 'tis the reverſe of the laſt Rule, *viz.* As the length propoſed: To the Standard (39,2) :: So is the Square of 60 (the vibrations of the Standard): To the Vibrations ſought.

Suppoſe for example, you would know what length a Pend. is, that vibrates 153 ſtrokes in a minute. The Square of 153 (*i. e.* 153 times 153) is 23409. Say, 23409. 3600 :: 39,2. 6. A Pend. then that vibrates 153 in a minute, is about 6 inches long.

On the other hand, if you would know how many ſtrokes a Pend. of 6 inches hath in a minute; Say, 6. 39,2 :: 3600. 23520. The ſquare root whereof is 153, and ſomewhat more.

Note, Becauſe 141120 is always the Product of the two middle terms multiplied together, therefore you need only to divide this number by the Square of the Vibrations, it gives the length ſought: by the length, it gives the ſquare of the Vibrations.

If you operate by the Logarithms, you will much contract your labour. For if you ſeek the length, 'tis but Subſtracting the Logarithm of the Square of the Vibrations, out of the Logarithm of 141120, which is 5.149588, and the Remainder is the Logarithm of the length ſought.

If you ſeek the Vibrations, it is but Subſtracting out of the aforeſaid Logarithm

rithm 5.149588, the Logarithm of the length given, and half the Reſidue is the Logarithm of the Vibrations required. The following examples will illuſtrate each particular.

To find the Length.

	Logarithms.
141120	5.149588
153 Squared is 23409	4.369382
Length is more than 6.	0.780206

To find the Vibrations.

	Logarithms.
141120	5.149588
6 inches long	0.778151
Square of the Vibr.	4.371437
Square-root, or numb. of Vibr. is 153, and ſomewhat more.	2.185718

According to the foregoing Directions, I have calculated the following Table, to Pendulums of various lengths: and have therein ſhewed the Vibrations in a minute,

and

and an hour, from 1 to 100 inches. If any desire a more minute account, I refer him to Mr *Smith's* Tables in his late Book. *Horolog. Disquis.* The reason why his calculation and mine differ, is because he measureth the length of the Pend. from the point of Suspension, to the lowet part of the Bob; and I only to the center of the Bob. His Standards are 6 ½ inches, and 41 inches; and mine is 39,2, for the reasons aforegoing.

A Table of Swings in a Minute, and in an hour, to Pendulums of several lengths.

Pend. length in inches	Vibrat. in a Minute.	Vibrat. in an Hour.	Pend. length in inches	Vibrat. in a Minute.	Vibrat. in an Hour.
1	375,7	22542	30	68,6	4116
2	265,6	15936			
3	216,9	13014	39,2	60.0	3600
4	187,8	11268			
5	168,0	10080	40	59,4	3564
6	153,3	9204	50	53,1	3186
7	142,0	8520	60	48,5	2910
8	132,8	7968	70	44,9	2694
9	125,2	7512	80	42,0	2520
10	118,8	7128	90	39,6	2376
20	84,0	5040	100	37,5	2250

The

The uſe of this Table is manifeſt, and needs no explication. As to the Decimals in the column of Minute-Swings, I have added them for the ſake of calculating the column of Hour-Swings; which would have been judged falſe without them, and would not have been exactly true without them.

§ 5. I have but one thing more to add to this Chap. of Pendulums, and that is, *To Correct their Motion.*

The uſual way is, to ſcrew up, or let down the Ball. In doing of which, a ſmall alteration will make a conſiderable variation of Time: as you will find by calculation, according to the laſt paragraph. To prevent the inconvenience of ſcrewing the Ball too high, or low, Mr *Smith* hath contriv'd a very pretty Table for dividing the Nut of a Pendulum Screw, ſo as to alter your Clock but a Second in a day. But by reaſon no Screw and Nut can be ſo made, as to be moſt exactly ſtrait and true, therefore it may happen, that inſtead of altering your Watch to your mind, you may do quite contrary; as inſtead of letting the Ball down, you may raiſe it higher, by the falſe running Ibid.

ning of the Nut upon the Screw.

Considering this irremediable inconvenience, I am of opinion, that Mr *Hugens*'s way would do very well, added to this. His way is, To have a small Weight, or Bob, to slide up and down the Pend. rod, above the Ball (which is immoveable.) But I would rather advise, that the Ball be made to screw up and down, to bring the Pend. pretty neer its gauge: and that this little Bob should serve only for more nice corrections; as the alteration of a Second, or &c. Which it will do, better than the Great Ball. For a whole turn of this little Bob, will not affect the motion of the Pend. near so much as a small alteration of the Great Ball.

Ibid. *de Centro Oscil.* Prop. 23.

The Directions Mr *Hugens* gives, about this little Corrector, is, That it should be equal to the weight of the Wire, or Rod of the Pend., or about a 50th part of the weight of the Great Ball, which he appoints to be three pounds.

Perhaps this Bob may do its office, if it be made to screw only up and down the lower part of the Rod, below the Ball. If not, you must make it slide above the Ball, or be screwed up and down there.

See-

Seeing this little Bob is not the only Corrector (as in Mr *Zulichem's* way) therefore it is not neceſſary to inſert here, that ingenious perſon's Table, ſhewing what alterations of Time will be made by ſliding the Bob up and down the rod. Only thus much may be obſerved in that Table of his, *viz.* That a ſmall alteration of the Corrector towards the lower end of the Pend., doth make as great an alteration of Time, as a greater raiſing or falling of it, doth make higher. Thus the little Bob raiſed 7 diviſions of the Rod, from the Center of Oſcillation, will alter the Watch 15 ſeconds; raiſed 15,2 'twill alter it 30". But whereas, if it be raiſed to 154,3 parts of the Rod, it will make the Watch go faſter 3 minutes, 15 ſeconds, the Watch ſhall be but 3'. 30" faſter, if the Bob be raiſed to 192,6. So that here you have but 15" variation, by raiſing the Bob above 38 parts; whereas lower, you had the ſame variation, when raiſed not above 7 or 8 parts.

From what hath been ſaid, it appears, that about half a turn of this little juſtening Bob, will at no time alter the Watch, above a ſecond in 24 hours: and that

above a whole turn, will not alter it ſo much, higher on the Rod; ſuppoſing that the Bob at every turn aſcended or deſcended a whole degree of the Rod; which perhaps it will not do in 20 turns: and conſequently, it will require many turns, to alter the Watch but one ſecond.

CHAP. VI.

The Antiquity, and general Hiſtory of Watch, or Clock-work.

§ 1. IT is probable, that in all Ages, ſome Inſtruments or other have been uſed, for the Meaſuring of Time. But the earlieſt we read of, is the *Dial* of *Ahaz*, Concerning which, little of certainty can be ſaid. The *Hebrew* word *Maʕaloth* doth properly ſignifie Degrees, Steps, or Stairs, by which we aſcend to any place. And ſo this word *Maʕaloth* is rendered *Ezek.* 40. 26. And accordingly the LXXII tranſlate the *Maʕaloth* of *Ahaz*, by the words Βαθμὸς, and Ἀναβαθμὸς, i. e.

2 *Kings* 20. 11. *Iſai.* 38. 8.

i. e. Steps or *Aſcents.* The like doth the *Syriack*, *Arabick*, and other Verſions.

Some pretend to give a deſcription of this *Dial* of *Ahaz:* but it being meer gueſſing, and little to my purpoſe, I ſhall not trouble the Reader with the various opinions about it.

Among the *Greeks* and *Romans*, there were two ways chiefly uſed to meaſure their Hours. One was by *Clepſydræ*, or Hour-glaſſes. The other by the *Solaria*, or Sun-dials. The Κλεψύδρα, ſays *Suidas* and *Phavorinus*, was Ὄργανον ἀστρολογικὸν ἐν ᾧ ἡ ὧραι μετροῦνται: *i. e. An Aſtronomical Inſtrument, by which the Hours were meaſured.* Alſo, *That it was a Veſſel, having a little hole in the bottom, which was ſet in the Courts of Judicature, full of water; by which the Lawyers pleaded.* This was, ſays *Phavorinus*, to prevent babbling, that ſuch as ſpake, ought to brief in their Speeches. *Lexic. in verbo* Κλεψύδρα

As to the Invention of thoſe Water-watches (which were, no doubt, of more common uſe, than only in the Law-Courts) the Invention, I ſay, of them, is attributed, by *Cenſorinus*, to *P. Cornelius Naſica*, the *Cenſor* (*Scipio Naſica*, *Pliny* calls him.) *De die Natali c.* 23.

The other way of measuring the Hours, with *Sun-dials*, seems, from *Pliny* and *Censorinus*, to have been an earlier invention than the last. *Pliny* says, that *Anaximenes Milesius*, the Scholar of *Anaximander*, invented Dialling, and was the first that shewed a Sun-dial at *Lacedæmon*. *Vitruvius* calls him *Milesius Anaximander*. This *Anaximander* or *Anaximenes* was cotemporary with *Pythagoras*, says *Laertius*; and flourished about the time of the Prophet *Daniel*.

Ibid.

Nat. Hist. l. 2. c. 76.

De Archit. l. 6. c. 48.

But enough of these ancient Time-engines, which are not very much to my purpose, being not pieces of Watch-work.

§. I shall in the next place take notice of a few Horological Machines, that I have met with; which, whether pieces of Clock-work, or not, I leave to the Readers judgment.

The first is that of *Dionysius*, which *Plutarch* commends for a very magnificent, and illustrious Piece. But this might be only a well delineated Sun-dial.

In the Life of *Dion*

Another Piece, is that of *Sapor* King of *Persia*. Whether that *Sapor*, who was cotemporary with *Constantine the Great*, I know

Euseb. Vit. Const. l. 3.

know not. *Cardan* ſaith it was made of Glaſs; that the King could ſit in the middle of it, and ſee its Stars riſe and ſet. But not finding whether this Sphere was moved by Clock-work, or whether it had any regular motion, I ſhall ſay no more concerning it. *De Subtil. l. 17.*

The laſt Machine I ſhall mention in this Paragraph, is one I find deſcribed by *Vitruvius*. Which to me ſeems to be a piece of Watch-work, moved by an equal influx of Water. *De Archi-tect. l. 9. c. 9.*

If the Reader will conſult the *French* Edition of *Vitruvius*, he will find there a fair Cut of it.

Among divers feats which this Machine performed (as ſounding Trumpets, throwing Stones, *&c.*) one uſe of it was, to ſhew the Hours (which were unequal in that age) through every month of the year. The words of *Vitruvius* are, *Æqualiter influens aqua ſublevat Scaphum inverſum (quod ab artificibus Phellos ſive Tympanum dicitur) in quo collocata regula, verſatilia tympana denticulis æqualibus ſunt perfecta. Qui denticuli alius alium impellentes, verſationes modicas faciant, ac motiones. Item aliæ Regulæ, aliaque Tympana ad eundem*

modum

modum dentata, quæ una motione coacta, verſando faciunt effectus, varietateſque motionum: in quibus moventur Sigilla, vertuntur Metæ, calculi aut Tona projiciuntur, Buccinæ canunt, &c. In his etiam, aut in columna, aut paraſtatica Horæ deſcribuntur; quas Sigillum egrediens ab imo virgulæ, ſignificat, in diem totum: quarum brevitates aut creſcentias, cuneorum adjectus aut exemptus, in ſingulis diebus & menſibus, perficere cogit.

The Inventer of this famous Machine, *Vitruvius* ſays, was one *Cteſibius*, a Barbers Son of *Alexandria*. Which *Cteſibius* flouriſhed under *Ptolomy Euergetes*, ſays *Athenæus*, l. 4. And if ſo, he lived about 240 years before our Saviours days; and might be cotemporary with *Archimedes*.

Vid. Philand. not. in Vitruv.

§ 3. Thus having given a ſmall account of the ancient ways of Meaſuring Time, it is time to come cloſer to our buſineſs, and ſay ſomething more particularly of Clock-work.

Which is thought to be a much younger invention, than the fore-mentioned Pieces; and to have had its beginning in *Germany*, within leſs than theſe 200 years.

It is very probable, that our Ballance Clocks,

Clocks, and ſome other *Automata*, might have their beginning there; or that Clock-work (which had long been buried in oblivion) might be revived there. But that Clock work was the Invention of that age purely, I utterly deny; having (beſides what goes before) two inſtances to the contrary, of much earlier date.

§ 4. The firſt example is the *Sphere* of *Archimedes*; who lived about 200 years before our Saviours days. There is no mention of this Sphere in *Archimedes* his extant works: but we have an account of it in others. *Cicero* ſpeaks of it more than once. In his 2d Book *De Naturâ Deorum*, are theſe words; "*Archimedem* "*arbitrantur plus valuiſſe in imitandis Sphæ-* "*ræ converſionibus, quam Naturam in effi-* "*ciendis*, &c. And in his *Tuſculane* Queſtions, the Collocutor, proving the Soul to be of a Divine Nature, argues from this Contrivance of *Archimedes*, and ſays, *Nam cum Archimedes Lunæ, Solis, quinque Errantium motus in Sphæram illigavit, effecit, &c.* The Senſe is, That *Archimedes* contrived a Sphere, which ſhewed the motion of the Moon, Sun, and five Planets.

Lib. 1. § 25. *Edit. Elzivir.*

But

But the moſt accurate deſcription is that of *Claudian*, in theſe words.

Epigr. in Sphær. Archimed. Vid. *Card. de Subtil. l.* 17.

Jupiter in parvo cum cerneret æthera vitro,
Riſit, & ad Superos talia dicta dedit:
Huccine mortalis progreſſa potentia curæ?
Jam meus in fragili luditur orbe labor.
Jura poli, rerumque fidem, legeſq; Deorum,
Ecce Syracuſius tranſtulit arte Senex.
Incluſus variis famulatur Spiritus aſtris,
Et vivum certis motibus urget opus.
Percurrit proprium mentitus Signifer annum.
Et ſimulata novo Cynthia menſe redit.
Jamque ſuum volvens audax induſtria mundum
Gaudet, & humana Sidera mente regit.
Quid falſo inſontem tonitru Salmonea mirror?
Æmula Naturæ parva reperta manu.

In *Engliſh* thus:

When Jove *eſpy'd in Glaſs his Heavens made,*
He ſmil'd, and to the other Gods thus ſaid:
Strange feats! when human art ſo far proceeds,
To ape in brittle Orbs my greateſt deeds.
The heav'nly motions, Natures conſtant courſe,
Lo! here old Archimede *to art transfers.*
Th' incloſed Spirit here each Star doth drive;
And to the living work ſure motions give.

The

The Sun in counterfeit his year doth run,
And Cynthia *too her monthly circle turn.*
Since now bold man has Worlds of's own deſcry'd
He joys, and th' Stars by human art can guide.
Why ſhould we ſo admire proud Salmons *cheats*
When one poor hand Natures chief work repeats.

From this deſcription it appeareth, that in this Sphere, the Sun, Moon, and other heavenly bodies, had their proper motion: and that this motion was effected by ſome encloſed *Spirit*. What this *encloſed Spirit* was, I cannot tell, but ſuppoſe it to be Springs, Wheels or Pullies, or ſome ſuch means of Clock-work: Which being hidden from vulgar eyes, might be taken for ſome Angel, Spirit, or Divine power; unleſs by Spirit here, you underſtand ſome aerious, ſubtiliz'd liquor, or vapours. But how this, or indeed any thing, but Clock-work, could give ſuch true, and regular motions, I am not able to gueſs.

§ 5. The next inſtance I have met with of ancient Clock-work, is that famous one in *Cicero*, which, among other irrefragable arguments, is brought in to prove, "That there is ſome intelligent, *De Nat. Deor.* Lib. 2. § 34.

" divine, and wiſe Being, that inhabiteth, " ruleth in, and is as an Architect of ſo " great a work, as the World is, as the Collocutor expreſſeth himſelf. His words (ſo far as they relate to my preſent purpoſe) are theſe: " *Cum Solarium vel deſcriptum, aut ex Aqua contemplere, intelligere declarari horas arte, non caſu, &c.* And a little after, *Quod ſi in Scythiam, aut in Britanniam, Sphæram aliquis tulerit hanc, quam nuper familiaris noſter effecit Poſidonius, cujus ſingulæ Converſiones idem efficiunt in Sole, & in Luna, & in quinque Stellis errantibus, quod efficitur in cœlo ſingulis diebus, & noctibus; quis in illa barbarie dubitet, quin ea Sphæra ſit perfecta ratione?* The ſum of the Authors meaning is, " That there were *Sun-dials* deſcribed, or " drawn [with Lines, after the manner as our Sun-dials are:] " and ſome made " with Water (which were the *Clepſydræ*, or Hour-glaſſes, before-mentioned.) " That *Poſidonius* had lately contrived a " Sphere, whoſe Motions were the ſame " in the Sun, Moon, and 5 Planets, as " were performed in the heavens each " day and night.

The

The age wherein this Sphere was invented, was *Cicero*'s time, which was about 80 years before our Saviours birth.

And that it was a piece of Clock-work, is not (I think) to be doubted, if it be considered, that it kept time with those celestial bodies, imitating both their annual, and diurnal motions, as from the description we may gather it did.

It may be questioned, whether those Machines were common or not: I believe they were rarities then, as well as Mr *Watson*'s and others are accounted now. But methinks it is hard to imagine, that so useful an Invention should not be reduced into common use; it being natural, and easie to apply it to the measuring of hours (tho unequal) especially in two such Ages, as those of *Archimedes* and *Tully* were, in which the Liberal Arts so greatly flourished.

§ 6. After the times last mentioned, I find little worth remark, till the last Age; in which Clock-work was revived, or wholly invented anew in *Germany*, as is generally thought, because the ancient pieces are *German* work. But who was the Inventer, or in what time, I cannot

Molyneaux, Scioth. Teleſcop. Ep. Dedic. diſcover. Some think *Sever. Boethius* invented it about the year 510. Perhaps it was in *Regiomontanus* his time (if not ſo early as *Boethius*) which was above 200 years ago. It is very manifeſt, it was before *Cardan*'s time, becauſe he ſpeaketh of it, as a thing common then. And he lived about 150 years ſince.

§ 7. As to thoſe curious contrivances in Clock-work, which perform ſtrange, ſurprizing feats, I ſhall ſay little. Dr. *Heylin* *Coſmog. l. 2.* tells us of a famous Clock and Dial in the Cathedral Church of *Lunden* in *Denmark*. "In the Dial (ſaith he) are to be "ſeen diſtinctly the Year, Month, Week-"day, and Hour of every day throughout "the Year; with the Feaſts, both move-"able and fixed; together with the Moti-"on of the Sun and Moon, and their paſ-"ſage thro each degree of the Zodiack. "Then for the Clock, it is ſo framed by "artificial Engines, that whenſoever it is "to ſtrike, two Horſe-men encounter one "another, giving as many blows apiece, "as the Bell ſounds hours: And on the "opening of a door, there appeareth a "Theatre, the Virgin *Mary* on a Throne, "with Chriſt in her arms, and the three "Kings

" Kings or *Magi* (with their ſeveral trains) " marching in order, doing humble reve- " rence, and preſenting ſeverally their " Gifts; two Trumpeters ſounding all " the while, to adorn the Pomp of that " Proceſſion.

To this I might add many more ſuch curious performances; but I rather chuſe to refer the Reader to *Schottus*, where he may find a great variety, to pleaſe him. *Magia Univerſ. P. 1. Proleg. & Magia Thaumaturg.*

CHAP. VII.

Of the Invention of Pendulum Watches.

§ 1. THE firſt that invented the way of applying Pendulums to Watch-work, was Mr *Chriſtian Hugens* of *Zulichem*; as he affirmeth of himſelf, with very cogent reaſons.

This excellent invention, he ſays, he put firſt in practice in the year 1657. and in the following year 1658, he printed a delineation and deſcription of it. *Hor. Oſcit. P. 3. Edit. Paris.*

Others

Others have claimed the honour of this Invention; among which, the great *Galileo* hath the moſt to be ſaid on his ſide. Dr. *John Joachim Becher* (who printed a Book when he was in *England*, entituled; *De Nova Temporis dimetiendi ratione Theoria, &c.* which he dedicated to the *Engliſh* Royal Society, *Anno* 1680.) he, I ſay, tells
p. 8. us, 'That the *Count Magalotti* (the Great 'Duke of *Tuſcany*'s Reſident at the Empe-'rors Court) told him the whole Hiſtory 'of theſe Pendulum Clocks, and denied 'Mr *Zulichem* to be the Author of them. Alſo, 'That one *Treffler* (Clock-maker to 'the Father of the then G. Duke of *Tuſcany*) 'related to him the like Hiſtory: and ſaid 'moreover, That he had made the firſt 'Pend. Clock, at *Florence*, by the com-'mand of the Great Duke, and by the di-'rection of his Mathematician *Galilæus à 'Galilæo*; a pattern of which was brought 'into *Holland*. And further he ſaith, 'That one *Caſpar Doms*, a *Fleming*, and 'Mathematician to *John Philip a Schon-'born*, the late Elector of *Mentz*) told him, 'that he had ſeen at *Prague*, in the time 'of *Rudolphus* the Emperor, a Pend. Clock, 'made by the famous *Juſtus Borgen*, Me-'chanick

'chanick and Clock-maker to the Empe-
'ror: which Clock the great *Tycho-Brahe*
'uſed in his Aſtronomical obſervations.

Thus far *Becher*. To which I may add, what is ſaid by the *Academie del Cimento*, *viz.* 'It was thought good to apply the 'Pendulum to the Movement of the *Clock*; 'a thing which *Galilæo* firſt invented, and 'his Son *Vincenzio Galilei* put in practice 'in the year 1649. Exper. made in the Acad. del Cimento tranſl. by Mr. Waller, p. 12.

As to theſe matters thus related by hear-ſay by *Becher*, and ſo expreſsly affirmed by the Academy, I have little to reply, but that Mr *Hugens* does expreſsly ſay, He was the Inventer, and that if *Galilæo* ever thought of any ſuch thing, he never brought it to any perfection. It is certain, that this Invention never flouriſhed till Mr *Hugens* ſet it abroad. Hugen lib:

§ 2. After Mr *Hugens* had thus invented theſe Pendulum Watches, and cauſed ſeveral to be made in *Holland*, Mr *Fromantil*, a *Dutch* Clock-maker, came over into *England*, and made the firſt that ever were made here: which was about the year 1662. One of the firſt Pieces that was made in *England*, is now in *Greſham-Colledg*, given to that Honorable Society by the

the late eminent *Seth*, Lord Biſhop of *Saliſbury*: which is made exactly according to Mr *Zulichem*'s directions.

§ 3. For ſeveral years this way of Mr *Zulichem* was the only method, *viz.* Crown-wheel Pendulums, to play between two cycloidal cheeks, &c. But afterwards Mr *W. Clement*, a *London* Clock-maker, contrived them (as Mr *Smith* ſaith) to go with leſs weight, an heavier Ball (if you pleaſe) and to vibrate but a ſmall compaſs. Which is now the univerſal method of the Royal Pendulums. But Dr *Hook* denies Mr *Clement* to have invented this; and ſays that it was his Invention, and that he cauſed a piece of this nature to be made, which he ſhewed before the *R. Society*, ſoon after the Fire of *London*.

Horolog. Diſquiſ. p. 3.

§ 4. The Uſe of theſe Pendulum Watches Mr. *Hugens* ſetteth forth in ſeveral inſtances. Particnlarly, he giveth two examples of their great uſe at *Sea*, in diſcovering the Difference of Meridians, more exactly than any other way: which he deduceth from the Obſervations of an *Engliſh*, and *French* Ship.

On *Land*, they were found very ſerviceable, among other uſes, particularly

to

to these two. 1. To measure the time more exactly, and equally than the Sun. 2. To be (as Sir *Christoph. Wren* first proposed) a perpetual, and universal Measure, or Standard, to which all Lengths may be reduced, and by which they may be judged, in all ages, and countries. For as our *Royal Society*, Mr *Hugens*, and *Mountonus* have proposed after Sir *Christopher Wren*) this *Horary foot*, or *Tripedal* length, which vibrateth Seconds, will fit all ages and places. But then respect must be had to the Center of Oscillation, which you have an account of in Mr *Hugens* his foresaid book, *de Horologio Oscillatorio*, as hath before been said.

§ 5. There is one contrivance more of Pendulums, still behind, *viz.* the *Circular Pendulum*: which is mentioned by Mr *Hugens* as his own, but is claimed by the ingenious Mr. *Hook* as really his. This Pend. doth not vibrate backward and forward, as those we have been speaking of do; but always round, round; the String being suspended above, at the tripedal length, and the Ball fixed below, as suppose at the end of the Fly of a common Jack.

The motion of this Circular Pend. is as regular, and much the same with what goeth before: and was thus far made very useful in Astronomical observations, by the said Dr *Hook*, *viz.* To give warning at any moment of its circumgyration, either when it had turned but a quarter, half, or any lesser, or greater part of its circle. So that here you had notice not only of a Second, but of the most minute part of a Second of Time. You may find a description of this *Pendulum*, and other matters belonging to it, in Dr *Hook's Lectiones Cutlerianæ: Animad. in Hevelius Mach. Caleſt. p.* 60.

CHAP. VIII.

Of the Invention of those Pocket-Watches, commonly called Pendulum Watches.

§ 1. THe reason they are called *Pendulum-Watches*, is from the regularity of their Strokes, and Motion. Which

Which exactneſs is effected by the govern-
ment of a ſmall Spiral Spring, running
round the upper part of the Verge of the
Ballance: which Spring is called the *Regu-*
lator.

§ 2. The firſt *Inventer* hereof, was
that ingenious and learned member of our
Royal-Society, Dr *Hook*: who contrived va-
rious ways of Regulation. One way was
with a Load-ſtone: another was with a
tender ſtrait Spring, one end whereof
played backward, and forward, with the
Ballance: So that the ballance was to this
Spring as the bob of a Pendulum, and the
little Spring, as the Rod thereof. And ſe-
veral other contrivances he had beſides of
this nature.

§ 3. But the Invention which beſt an-
ſwered expectation, was at firſt, with two
Ballances: of which I have ſeen two ſorts,
though there were ſeveral others. One
way was without Spiral Springs, the
other with. They both agreed in this,
that the outward Rims of both the Bal-
lances, had alike number of Teeth; which
running in each other, cauſed each Bal-
lance to vibrate alike.

But as to the former of these, which had no Spiral Spring: the Verges of its Ballances, had each but one Pallet apiece, about the middle of the Verge. The Crown-wheel lay (contrary to others) reversed, in the middle of the Watch, in the place, and after the manner of the Contrate-wheel. The teeth of this Crown-wheel, were cut after the manner of Contrate-wheel teeth, *viz.* lying upwards, but very wide apart, so as that the Pallets (which were about one tenth of an inch long, and narrow) might play in and out between each tooth. The Verges of the two Ballances, were set one on one side, the other on the other side of the Crown-wheel, so that the Pallets might play freely in its teeth. And when the Crown-wheel in moving round, had delivered its self of one Pallet, the other Pallet on the opposite side, was drawn on to make its Beat, by means of the motion which the other Ballance had given its Ballance, (the two Ballances moving one another, as hath been said in the beginning of this Paragraph.) And so the same back again.

It may be here noted, that for the more clear underſtanding of the laſt contrivance, I have deſcribed the two Ballances, as having Teeth on the edges of their Rims, running in one another. But the contrivance was really thus, There was a ſmall Wheel under each Ballance, proportioned to the width of the Crown-wheel. But the Ballances were much larger. And ſo the Teeth of theſe two little foreſaid Wheels or Ballances, running in one another, moved the larger Ballances above them, all one, as if theſe two great Ballances had been toothed and played in each other.

§ 4. The other way, with two Ballances alſo, moving each other, (as was ſaid in the beginning of the laſt §) had a Spiral Spring to each Ballance, for its Regulator. In this Invention, only one Ballance had the Pallets, as the common Ballances have: and the Crown-wheel operated upon it, according to the uſual way. But then when this Ballance vibrateth, it giveth the ſame motion backward and forward, to the other ballance; as hath been ſaid.

The

The first of these two ways, was never prosecuted so far, as perhaps it deserved. And the excellency of the latter is, that no jirk, or the most confused shake, can in the least alter its Vibrations. Which it will do in the best Pendulum Watch with one ballance now commonly used. For if you lay one of these Watches upon a Table, and by the Pendant jirk it backward and forward, you will put it into the greatest hurry; whereas the last mentioned Watch, with two ballances, will be nothing affected with it. But notwithstanding this inconvenience, yet the Watch with one ballance and one Spring (which was also Dr. *Hooks* Invention) prevailed, and grew common, being now the universal Mode: but of the other very few were ever made. The reason hereof, I judge, was the great trouble and vast niceness required in it, and perhaps a little foulness in the ballance-teeth may retard the motion of the ballances. But the other is easier made, and performeth well enough, and in a pocket is scarce subject to the aforesaid disorder, which is caused rather by a turn, than a shake.

§ 5.

§ 5. The time of theſe Inventions was about the year 1658, as appears (among other evidence) from this inſcription, upon one of the aforeſaid double Ballance-Watches, preſented to K. *Charles* II, *viz. Robert Hook inven.* 1658. *T. Tompion fecit* 1675.

This Watch was wonderfully approved of by the King; and ſo the Invention grew into reputation, and was much talked of at home, and abroad. Particularly its fame flew into *France*, from whence the Dauphine ſent for two; which that eminent Artiſt Mr. *Tompion* made for him.

§ 6. Dr. *Hook* had long before this, cauſed ſeveral pieces of this nature, to be made, altho they did not take till after 1675. However he had before ſo far proceeded herein, as to have a Patent (drawn, tho not ſealed) for theſe, and ſome other Contrivances, about Watches, in the year 1660. But the reaſon why that Patent did no further proceed, was ſome diſagreement about ſome Articles in it, with ſome Noble Perſons who were concerned for the procuring it. The ſame ingenious Dr. had alſo a Grant for a Patent for this laſt way of Spring Watches in

in the year 1675: but he omitted the taking it out, as thinking it not worth the while.

§ 7. After these Inventions of Dr. *Hook*, and (no doubt) after the Publication of Mr. *Hugens's* book *de Horolog. Oscil.* at *Paris* 1673 (for there is not a word of this, tho of several other Contrivances) after this, I say, Mr. *Hugen's* Watch with a Spiral Spring came abroad, and made a great noise in *England*, as if the Longitude could be now found. One of these the Lord *Bruncker* sent for out of *France*, (where Mr *Hugens* had a Patent for them) which I have seen.

This Watch of Mr. *Zulichem's* agreed with Dr. *Hook's*, in the application of the Spring to the ballance: only Mr. *Zulichem's* had a longer Spiral Spring, and the Pulses and Beats were much slower. That wherein it differs, is 1. The Verge hath a Pinion instead of Pallets; and a Contrate-wheel runs therein, and drives it round, more than one turn. 2. The Pallets are on the Arbor of this Contrate-wheel. 3. Then followeth the Crown wheel, &c. 4. The ballance, instead of turning scarce quite round (as Dr. *Hook's*) doth turn several rounds every vibration. § 8.

§ 8. As to the great abilities of Mr *Hugens*, no man can doubt, that is acquainted with his Books, and his ſhare in the Philoſophical Tranſactions, &c. But I have ſome reaſon to doubt, whether his fancy was not firſt ſet on work, by ſome Intelligence he might have of Dr *Hook*'s Invention, from Mr *Oldenburgh*, or others his correſpondents here in *England*.

But whether or no that ingenious perſon doth owe any thing herein to our ingenious Dr *Hook*, it is however a very pretty, and ingenious contrivance; but ſubject to ſome defects: *viz.* When it ſtandeth ſtill, it will not vibrate, until it is ſet on vibrating: which, tho it be no defect in a Pendulum Clock, may be one in a Pocket-Watch, which is expoſed to continual jogs. Alſo, it doth ſomewhat vary in its Vibrations, making ſometimes longer, ſometimes ſhorter turns, and ſo ſome ſlower ſome quicker vibrations.

I have ſeen ſome other contrivances of this ſort, which I mention not, becauſe they are of younger ſtanding. But theſe two (of Dr *Hook* and Mr *Hugens*) I have taken notice of, becauſe they were the firſt that ever appeared in the world.

CHAP. IX.

The Invention of Repeating Clocks.

§ 1. THe *Clocks* I now ſhall ſpeak of, are ſuch as by pulling of a String, &c. do ſtrike the Hour, Quarter, or Minute, at any time of the day and night.

§ 2. Theſe Clocks are a late Invention of one Mr *Barlow*, of no longer ſtanding than the latter end of K. *Charles* II. about the year 1676.

This ingenious Contrivance (ſcarce ſo much as thought of before) ſoon took air, and being talked of among the *London* Artiſts, ſet their heads to work; who preſently contrived ſeveral ways to effect ſuch a performance. And hence aroſe the divers ways of *Repeating work*, which ſo early might be obſerved to be about the Town, every man almoſt practiſing, according to his own Invention.

§ 3.

§ 3. This Invention was practiſed chief-
, if not only, in larger Movements,
l K. *James* II.'s Reign: at which time it
is transferred into Pocket-Clocks. But
re being ſome little conteſt concern-
g the Author hereof, I ſhall relate the
e matter of fact, leaving the Reader to
own judgment.

About the latter end of K. *James* II.'s
gn, Mr *Barlow* (the ingenious Inventer
ore-mentioned) contrived to put his
ention into Pocket-watches; and en-
voured (with the Lord Chief Juſtice
kbone, and ſome others) to get a Patent
it. And in order to it, he ſet Mr *Tom-*
, the famous Artiſt, to work upon it:
o accordingly made a Piece according
is directions.

Mr *Quare* (a very ingenious Watch-
er in *London*) had ſome years before
thinking of the like Invention: but
bringing it to perfection, he laid by
houghts of it, until the talk of Mr *Bar-*
Patent revived his former thoughts;
h he then brought to effect. This
g known among the Watch-makers,
all preſſed him to endeavour to hin-
Mr *Barlow*'s Patent. And according-

ly applications were made at Court, and a Watch of each Invention, produced before the King and Council. The King, upon tryal of each of them, was pleaſed to give the preference to Mr *Quare's*: of which, notice was given ſoon after in the Gazette.

The difference between theſe two Inventions was, Mr *Barlow's* was made to Repeat by puſhing in two pieces on each ſide the Watch-box: one of which Repeated the Hour, the other the Quarter. Mr *Quare's* was made to Repeat, by a Pin that ſtuck out near the Pendant which being thruſt in (as now 'tis done by thruſting in the Pendant) did Repeat both the Hour, and Quarter, with the ſame thruſt.

It would (I think) be very frivolous, to ſpeak of the various contrivances, and methods of Repeating work, and the Inventers of them; and therefore I ſhall ſay nothing of them.

CHAP

CHAP. X

Numbers for ſeveral ſorts of Movements.

I Think it may be very convenient to ſet down ſome Numbers, fit for ſeveral Movements; partly, to be as Examples to exerciſe the young Reader, in the foregoing Art of Calculation: and partly, to ſerve ſuch, who want leiſure or underſtanding to attain to this Art.

§ 1. But firſt it may be requiſite, to ſhew the uſual way of Watch-makers writing down their Numbers, which is ſomewhat different from that in the preceding Book.

Their way repreſenteth the Wheel and Pinion, on the ſame Spindle; not as they play in one another. Thus the numbers of an old Houſe-Watch, of 12 hours, is written thus;

My

My way:	The Watch-makers way.
4)48	48
7)56	56—4
6)54	54—7
19	19—6

According to my way, the Pin. of Report [4] drives the Dial-wheel [48:] the Pinion [7] plays in the Great-wheel [56] *&c.* But according to the other way, the Dial-wheel ſtands alone; the Great-wheel hath the Pinion of Report on the ſame arbor: the Wheel [54] hath the Pin: [7] and the Crown-wheel [19] the Pin: [6] on the ſame Spindles.

This latter way (tho very inconvenient in Calculation) repreſenteth a piece of work handſomely enough, and ſomewhat naturally.

§ 2. Numbers of an 8 *day Piece*, with 16 turns the Barrel, the Pend. vibrates Seconds, and ſhews Minutes, Seconds, *&c.*

The Watch-part.	The Clock part.
8)96	8)78
8)60—48)48—6)72	6)48 8 pins.
7)56	6)48
—	6)48
30	

In

In the Watch-part, the Wheel 60 is the Minute-wheel, which is ſet in the middle of the Clock, that its Spindle may go thro the middle of the Dial-plate to carry the Minute-hand.

Alſo on this Spindle is a Wheel 48, which driveth another Wheel of 48, which laſt hath a Pinion 6, which driveth round the Wheel 72 in 12 hours. Note here two things: 1. That the two Wheels 48, are of no other uſe, but to ſet the Pinion 6 at a convenient diſtance from the Minute-wheel, to drive the Wheel 72, which is concentrical with the Minute-wheel. For a Pinion 6 driving a Wheel 72, would be ſufficient, if the Minute-hand and Hour-hand had two different centers. 2. Theſe numbers, 60-48)48-6)72, ſet thus, ought (according to the laſt §) be thus read, *viz.* The Wheel 60, hath another Wheel 48 on the ſame Spindle; which Wheel 48 divideth, playeth in, or turns round another Wheel 48; which hath a Pinion 6 concentrical with it: which Pinion driveth, or divideth a Wheel of 72. For a Line parting two numbers (as 60—48) denoteth thoſe two numbers to be concentrical, or to be placed upon the

the ſame Spindle. And when two numbers have a hook between them (as 48)48) it ſignifies one to run in the other, as hath before been hinted.

In the Striking-part, there are 8 Pins on the Second wheel 48. The Count-wheel may be fixed unto the Great-wheel, which goeth round once in 12 hours.

§ 3. A Piece of 32 *days*, with 16, or 12 turns both parts: the Watch ſheweth Hours, Minutes, and Seconds; and the Pend. vibrateth Seconds.

The Watch-part,

With 16 turns.	With 12 turns.
16)96	12)96
9)72	9)72
8)60--48)48--6)72	8)60--48)48--6)72
7)56	7)56
—	—
30	30

The Striking part.

With 16 turns.	With 12 turns.
10)130	8)128
8)96 { 24 pins / 12)39	8)104 { 26 pins / 8)24
6)72 Double hoop.	8)96 Double hoop.
6)60	8)80

The

The Pinion of Report is fixed on the end of the arbor of the Pin-wheel. This Pinion in the firſt is 12, the Count-wheel 39 ; thus, 12)39. Or it may be 8)26. In the latter (with 12 turns) it may be 6)18, or 8)24.

§ 4. *A two month Piece*, of 64 days; with 16 turns; Pend. vibrateth Seconds, and ſheweth Minutes, Seconds, &c.

Watch-part.	Clock-part.
9)90	10)80
8)76	10)65
8)60--48)48--6)72	9)54 { 12 pins —8)52
7)56	5)60-Double Hoop
30	5)50

Here the third Wheel is the Pin-wheel; which alſo carrieth the Pinion of Report 8, driving the Count-wheel 52.

Or thus.

Watch-part.	Clock-part.
8)80	6)144
8)76	6)78 { 26 pins —8)24
8)60--48)48--6)72	6)72-DoubleHoop
7)56	6)60
30	

§ 5. A piece of 13 *weeks*, with Pendulum, Turns, and Motions, as before.

The Watch part.

8)96 Or thus.	6)72
8)88	6)66
8)60--48)48--6)72	6)48--48)48--6)72
7)56	6)45
30	30

The Clock part.

8)72 Or thus.	5)145
8)64—37)30	6)90 —30 pins
8)48—12 pins	—24)62
6)48 Double Hoop	6)72
5)40	6)60

§ 6. A *Seven Month* Piece, with Turns, Pendulum, and Motions, as before.

The Watch.	The Clock.
8)60	8)96
8)56	8)88—27)12
8)48	8)64—16 pins
6)45--48)48-6)72	6)48 Double Hoop
5)40	6)48
30	

§ 7

§ 7. A *Tear Piece*, of 384 days, with Turns, Pendulum, and Motions, as before.

The Watch.	The Clock.
12)108	10)120
9)72	8)96—36)9
8)64	6)78 26 pins
8)60--48)48·6)72	6)72 Double Hoop
7)56	6)60
30	

If you had rather have the Pinion of Report, on the Spindle of the Pin-wheel, it muſt be 13)39.

§ 8. A Piece of 30 *Hours*, Pendulum about 6 inches.

The Watch.	The Clock.
12)48	8)48
6)78	6)78 13 pins
6)60	6)60
6)42	6)48
15	

§ 9. A Piece of 8 *days*, with 16 turns, *Pendulum* about 6 *inches*, to ſhew Minutes, Seconds, *&c.*

The Watch.

8)96
8)64—48)48—6)72
8)60
8)40 The Seconds Wheel.

15

The Clock may be the ſame with the 8 day piece before, § 2.

§ 10. A *Month Piece* of 32 days, with Pendulum, Turns, and Motions, as the laſt.

The Watch.

8)64
8)48
6)48—48)48—6)72
6)45
6)30 Seconds Wheel.

15

The Clock may have the ſame numbers, as the Clock § 3.

§ 11. A *Tear Piece* of 384 days, with Pendulum, Turns, &c. as the laſt.

The

The Watch part.

10)90
8)64
7)56
6)48
6)45—48)48—6)72
6)30

Seconds Wheel.

15

Or thus, with a Wheel leſs, and not to ſhew Minutes and Seconds.

8)96
6)72—36)9
6)66
6)60
6)54

19

In the latter of theſe two Numbers, the Pinion of Report is 36, on the Second Wheel. The Dial Wheel is 9.

The *Clock-part* may have the ſame Numbers, as the Year-piece before § 7.

§ 12. An 8 *Day* Piece, to ſhew the Hour and Minute, *Pend.* about 3 *inches* long.

6)96
8)64--6)72
7)49
6)36

19

The Clock may have the ſame numbers, as the 8 day piece before, § 2.

Automata ſhewing the Motion of the Celeſtial Bodies.

§ 1. Numbers for the Motion of the *Sun* and *Moon*. See before in Chap. 2. Sect. 5. § 3, 4.

§ 2. Numbers to ſhew the Revolution of the Planet *Saturn*, which conſiſts of 10759 days.

On the Dial-wheel.

5)69
4)52
4)48
4)40

If you would make it depend upon a Wheel going round in a year, thus.

10)59
6)30

or thus, 4)118

Note, The lowermoſt Pinion in theſe, and the following numbers, is to be fixed concentrical to the Wheel, which is to drive the Motion, *viz.* the Dial-wheel, Year-wheel, or *&c.*

§ 3. Numbers for the Planet *Jupiter*, whoſe Revolution is 4332 ½ days.

On the Dial-wheel.

4)48
4)40
4)36
4)32

Or thus, on the Year-wheel.

6)71

Note here, That the two laſt numbers of

of *Saturn*, may be the two firſt of *Jupiter* alſo.

By the permiſſion of my ingenious friend Mr *Flamſteed*, I here inſert a deſcription of Mr *Olaus Romer*, the *French* King's Mathematician's Inſtrument, to repreſent the Motion of *Jupiter's Satellites*; a copy of which he ſent to Mr *Flamſteed* in 1679.

Upon an axis (which turns round once in 7 days) are four Wheels fixed: one of 87 teeth; a ſecond of 63; the third 42; and the laſt of 28 teeth. On another axis run 4 other Wheels (or Pinions you may call them) which are driven by the aforeſaid Wheels. The firſt is a Wheel, or Pinion of 22 leaves, driven by the Wheel 87, which carrieth round the firſt Satellite. The ſecond is 32, driven by the Wheel 63, which carrieth round the ſecond Satellite. The third hath 43 leaves, driven by the Wheel 42, which carrieth the third Satellite. And laſtly, is the Pinion 67, driven by the Wheel 28, which carrieth round the fourth Satellite.

On the firſt axis is an Index, that pointeth to a circle divided into 168 parts, which are the hours in 7 days.

On

On the other axis all the Pinions run concentrically, by means of their being hollow in the middle. In the midſt of them all, the axis of *Jupiter* himſelf is fixed, with a little Ball at the top, repreſenting *Jupiter*'s body. On the ends of 4 ſmall Wires, fixed in the four ſeveral Sockets of the aforeſaid Pinions, may 4 leſſer Globules be placed (at their due diſtance from *Jupiter*'s Globule) to repreſent the 4 Satellites going round that Planet.

§ 4. Numbers for *Mars*, whoſe Revolution is 1 year 322 days.

On the Dial-wheel:

4)48 The two laſt Numbers of *Saturn* may be the two firſt of *Mars* alſo.
4)40
4)45

§ 5. Numbers for *Venus*, whoſe Revolution is in 224 days.

On the Dial-wheel.

4)32 *Note*, The laſt number of *Jupiter* may be the firſt of *Venus*.
4)32
4)28

§ 6. Numbers for *Mercury*, whoſe Revolution is near 88 days.

On

On the Dial-wheel.

4)56
4)52

§ 7. Numbers to repreſent the Motion of the *Dragon's Head* and *Tail*, (near 19 years) to ſhew the *Eclipſes* of the Sun and Moon.

On the Dial-wheel. On the Year-wheel.

4)48 4)76
4)40 Note, The two laſt numbers
4)44 of *Saturn* may be the two firſt of
4)42 this on the Dial-wheel.

As to the placing theſe ſeveral Motions on the Dial-plate, I ſhall leave it wholly to the Work-mans contrivance. He may perhaps make them to repreſent the *Copernican*, or ſome other Syſtem.

Numbers for Pocket-Watches.

§ 1. A Watch to go 8 *Days*, with 12 turns, to ſhew Minutes and Seconds, the Train 16000.

6)96
6)48—12)48—12)36.
6)45 On the Wheel [42] is the Second's
6)42 hand placed, and on the Wheel
19 [48] the Minute hand.

§ 2. Another of the ſame, without Minutes and Seconds, to go with only 8 turns.

20)10

6)66
6)60
5)50
5)45

19

§ 3. A Pocket-Watch of 32 *Hours*, with 8 turns, to ſhew Minutes and Seconds, Train as the laſt.

12)48
6)48—12)48—12)36
6)45
6)42—Seconds Hand.

19

§ 4. The uſual Numbers of 30 hours Pendulum Watches, with 8 turns, to ſhew the Hour and Minute.

12)48
6)54—12)48—12)36
6)48
6)45

15

§ 5.

§ 5. The uſual Numbers of the old 30 hours Pocket-watches.

With 5 Wheels.	With 4 Wheels.
10)30	6)32
7)63	6)66
6)42	5)50
6)36	5)45
6)32	17
15	

If any of the Numbers of the preceding Wheels and Pinions ſhould not pleaſe the Reader, he may eaſily correct them to his mind, by the Inſtructions in the foregoing Book. The way in ſhort is this: Divide the Wheel by the Pinion, and ſo find the number of turns, according to Chap. 2. Sect. 1. § 2. Multiply the Pinion you like better, by this number of turns, and the Product is the Wheel. Thus in the 8 day Pocket-watch § 1, if you think the Great-wheel too large, you make it inſtead of 6)96(16 thus, *viz.* 5)80(16: *i.e.* chuſing the Pinion only 5, and multiplying it by 16 (the turns) the Wheel will be 80.

CHAP. XI

Tables of Time relating to Watch-work.

A Table of Time.

Seconds.	Minutes.	Hours.	Day.	Week.	Month.	Year.
60						
3600	60					
86400	1440	24				
604800	10080	168	7			
2592000	43200	720	30	4		
31536000	525600	8760	365	52	12	

The foregoing Table will be of good uſe in Calculation, for the ready finding out the parts of Time: which is thus. Find the parts of time you ſeek for, the number in the concurrence of Squares, is the anſwer to your queſtion. Thus, ſuppoſe you ſeek for the number of Seconds in

in a Year: in the Square under *Seconds*, and in the ſame line with *Year* (which is the lowermoſt Square on the left hand) is the number ſought, *viz.* 315, &c. So Minutes in a Month, are 43200.

If you would know any number, where there is the addition of an odd number to it, as the Seconds in a Month and one day; add the Seconds in a month (which are 259----) and the Seconds in a Day (which are 86----) and you have the number ſought, *viz.* 2678400.

A Table to ſet a Watch by the Fixed Stars.

Night	Hour.	Min.	Sec.	Night	Hour.	Min.	Sec.
1	0	3	57	16	1	3	20
2	0	7	54	17	1	7	17
3	0	11	51	18	1	11	14
4	0	15	47	19	1	15	11
5	0	19	44	20	1	19	8
6	0	23	41	21	1	23	5
7	0	27	38	22	1	27	1
8	0	31	35	23	1	30	58
9	0	35	32	24	1	34	55
10	0	39	29	25	1	38	52
11	0	43	26	26	1	42	49
12	0	47	23	27	1	46	46
13	0	51	29	28	1	50	43
14	0	55	26	29	1	54	40
15	0	59	23	30	1	58	36

Explanation of the Table.

This Table ſhews how much the Sidereal, goeth faſter than the Solar day, in any number of nights for a month. So that obſerving by your Watch, the nice time when any fixed Star cometh to the Meridian, or any other point of the Heavens: if after one Revolution of that ſame Star to the ſame point, your Watch goeth 3'. 57" ſlower than the Star; or after two nights 7'. 54"; or 16 nights, 1 h. 3'. 20", &c. then doth your Watch keep time rightly with the Mean motion of the Sun. If it vary from the Table, you muſt alter the length of your Pend. to make it ſo keep time.

To obſerve the time nicely, when the Star cometh again to the ſame point of the heavens, 'tis neceſſary to make the obſervation with a Teleſcope, that hath croſs threads in the focus of the object-glaſs; and ſo leaving the Teleſcope fixed in the ſame poſture, till a ſecond Obſervation. You may do this with the teleſcopular ſights of a Quadrant, or Sextans, and ſo leaving it ſtanding until anoher night of Obſervation. Or for want of this more nice way, you may do it by looking along by the edge of two Strings, ſuſpended with Plumbets,

in

in a room, at ſome diſtance from one another. Or by looking at the edge of a Chimney, &c. as Mr *Watſon* hath directed, at the end of Mr *Smith*'s *Horol. Diſquiſ.* But to make a tolerable obſervation any of theſe laſt ways, 'tis neceſſary to have a Candle ſhine upon the edge of the furthermoſt String, or Chimney; without which you cannot ſee exactly when the Star cometh thereto.

A Table ſhewing the Variations made in the true Hour of the Day, by the Refraction of the Sun in the Equator, and both the Solſtices.

Sun's altitude. Deg.	Sun's Refraction. ′ ″	Variation at the N. Solſtice. ′ ″	Variation at the Equator. ′ ″	Variation at the S. Solſtice. ′ ″
00	33 00	4 34	3 32	4 38
1	23 00	2 34	2 28	3 19
2	17 00	2 24	1 49	2 31
3	13 30	1 46	1 27	2 2
4	11 30	1 29	1 12	1 40
5	9 30	1 12	1 1	1 23
6	7 30	0 56	0 49	1 17
7	7 00	0 52	0 44	1 16
8	6 00	0 43	0 39	1 8
9	5 00	0 36	0 34	1 2
10	4 40	0 25	0 29	1 2

Remarks

Remarks upon the Table.

The Column of the Sun's Refractions, I owe to that accurate obſerver of the celeſtial motions, Mr *Flamſteed*. Which Refractions, altho in the Table the ſame, yet do differ at different ſeaſons of the year, nay perhaps, according to the different temperature of the air ſometimes, in the ſame day. Thus Mr *Flamſteed* found the Refractions in *February*, very different from thoſe in *April*: and it is obſerved, that the Refractions are commonly greater, when the *Mercury* is higher in the Barometer.

The Table therefore doth not ſhew what the Refractions always are, but only about the middle quantity of them, at every degree, of the 10 firſt of the Sun's altitude. And accordingly I have calculated the Variations thereby made in the hour of the day.

Theſe Variations of the hour are greater or leſſer, according as the angle of the Sun's diurnal motion is acuter with the horizon. The reaſon is plain; becauſe as the Sun appears by refraction higher than really

really he is 3 ſo this falſe height doth affect the hours in Winter, more than the Summer half year.

There is no ray indeed of the Sun, but what cometh refracted to a Sun-dial: and conſequently, there is no Dial but what goeth more or leſs falſe (except at Noon in Dials that caſt a Shade, where the refraction makes no variation.) But the Refraction decreaſeth apace, as the Sun gets higher, and cauſeth a variation of not above half a minute, at 10 degrees of the Sun's altitude; except when the Sun is in, or near the Southern Tropick. Nearer than half a minute, few common Sun-dials ſhew the time. And therefore, partly for this reaſon, and partly, becauſe Mr. *Flamſteed's* obſervations reach not much farther, I have calculated my Table to only 10 degrees.

The Table needs little explication. For having the Sun's height, you have againſt it, in the next Column, the Refraction: and in the 3 next the alterations of the hour, at 3 times of the year. Taking therefore by a Quadrant the Sun's altitude, and obſerve at the ſame time, the hour of the day by a Sun-dial, by the Ta-

ble, you see how many minutes, and seconds, the Dial is too fast. As at the Sun-rising a Sun-dial is too fast 4'. 34", about *June* 11, and 3'. 32", about *Mar.* 12. and *Sept.* 12, and 4' 38" about *Dec.* 11.

Ad-

Addenda.

TO the Fifth part of the Rule in § 6. p. 21. If you have occaſion to lay the Pinion of Report upon any other Wheel, and not the great-Wheel, you may do it by this Rule, *As the Beats in one turn of any Wheel; To the Beats in an hour: : So are the hours of the Dial; To the Quotient of the Hour-wheel divided by the Pinion of Report.*

To page 66. Suppoſe in altering an old Watch, you would have it ſhew minutes, as well as hours; you may do it thus: Divide the Beats in one turn of the Great-wheel, by the Beats in an hour; the Quotient will ſhew in how many hours the Great-wheel goeth round once. If the Beats in the Great wheel exceed the Train, you muſt chuſe your Minute-wheel firſt, and multiply it by the Quotient; this will give the Pin. of Report. But if the Train exceeds the Beats of the Great-wheel, you muſt chuſe the Pin. of Rep. and multiply the Quotient by it: the product is the Minute-wheel.

But

But it often falls out, that the Train and Beats of the Great-wheel will not exactly measure one another: if so, the best way is to half the two numbers, as far as they will equally admit of halfing; or divide them by some common divisor, and so having brought them to as small numbers as you can, you may suppose them to be a Wheel and Pinion, and reduce them to lesser numbers. by Chap. 2. Sect. 2. § 5. Thus suppose you would make the old dull Movement there mentioned, a Minute-watch; you may reduce the numbers of the Great-wheel 21888. and the Train 9368, to a Pinion and Wheel 28) 12. Which Pin. 28 being set upon the Spindle of the Gr. Wh. will drive a Wheel 12 round once in an hour, to shew Minutes. If you make this Wh. 12 drive another of 48; (concentrical to which, is a Pin. 12 driving a Wheel 36 (which Wheel is concentrical with the Minute-wheel) this will carry a Hand round in 12 hours. But in this case, you must place the Pin. 28 on the Spindle of the Gr. Wh. so as to slide round stiffly, when you turn the Minute-hand to rectifie the Watch.

FINIS.